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AI-informed Holistic Electric Vehicles Integration Approaches for Distribution Grids

D8.1

Design of Southern Europe Demo

January 2026 (M20)

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EXECUTIVE SUMMARY

Deliverable **D8.1 – Design of the Southern Demo** defines the technical and functional design of the **AHEAD Southern Demo**, covering two representative DSO areas: **Milano (Unareti)** and **Kranj (Elektro Gorenjska)**. The report translates AHEAD's holistic, AI-informed approach for **integrating electric vehicles into distribution grids** into site-specific architectures, requirements, and interoperability frameworks. In Milano, the demo focuses on **smart and bidirectional charging** for DSO fleet vehicles at a primary substation, leveraging advanced **SCADA/ADMS** systems and **OCPP/IEC 61850** protocols. In Kranj, the **Arriva bus depot** serves as a hybrid live–simulation testbed for **flexibility activation and AI-assisted planning** under real MV/LV conditions. Together, the two sites demonstrate complementary strategies for enhancing grid resilience, efficiency, and flexibility in support of Europe's sustainable e-mobility transition.

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LIST OF ACRONYMS

AC	Alternating Current
ADMS	Advanced Distribution Management System
AI	Artificial Intelligence
AMI	Advanced Metering Infrastructure
CPO	Charging Point Operator
DC	Direct Current
DER	Distributed Energy Resources
DMS	Distribution Management System
DSO	Distribution System Operator
EV	Electric Vehicle
FO	Fibre Optic
HC	Hosting Capacity
HDT	Heavy Duty Tucks
HDV	Heavy Duty Vehicles
HV	High Voltage
IDMS	Integrated Distribution Management System
LV	Low Voltage
MV	Medium Voltage
P2P	Point-to-Point Communication
PCC	Point of Common Coupling
PCC	Points of Common Coupling
PLC	Power Line Communication
PTO	Public Transport Operator
RES	Renewable Energy Sources
SoC	State of Charge
SONCEE	Slovenian operating instructions on RES integration
UC	Use Case
V2G	Vehicle-to-Grid
WP	Work Package

1. INTRODUCTION

The AHEAD project advances holistic approaches for integrating electric vehicles (EVs) into distribution grids, with a strong focus on Distribution System Operator's (DSO) centric operation, customer participation, and interoperability across mobility and energy domains. Rapid EV uptake, coupled with the growth of Distributed Energy Resources (DER), notably rooftop PV and battery energy storage, creates new operational challenges at medium-voltage (MV) and low-voltage (LV) levels: local congestion, voltage excursions, and increased variability. At the same time, EV charging flexibility offers an opportunity to relieve grid constraints, defer reinforcement, and support a just and efficient energy transition. AHEAD addresses this opportunity by developing data-driven forecasting, coordination, and control methods, validated through real-world demonstrations.

This deliverable, **D8.1 – Design of the Southern Demo**, defines the design concept, functional requirements, technical architecture, and risk management approach for the Southern European Demo Site. The document translates project-level objectives into site-specific specifications. The scope of the deliverable is to consolidate: (i) the local energy and mobility context relevant to the DSO, (ii) the demonstrator's functional requirements, and (iii) the logical and physical architecture spanning field devices, edge platforms, and cloud/IT services.

The document is structured as follows. Section 2 summarises the DSO and local energy ecosystems for Milano and Kranj, including grid topology, digitalisation state (SCADA/ADMS/AMI), consumption and mobility patterns, and data availability. Section 3 details the Milano Demo Site, covering the site overview, Use Case testing approach, functional requirements grouped by data acquisition, communications and interoperability, control and optimisation, and monitoring, followed by the technical architecture (hardware and software). Section 4 mirrors this structure for Kranj to enable cross demo comparison. Finally, Section 5 concludes with key design decisions, expected benefits, and next steps toward deployment and validation.

This document assumes timely access to site and operational data, subject to applicable confidentiality and data protection agreements. Dependencies with other technical activities, such as, for example, forecasting model development, optimisation services, and cybersecurity frameworks, are managed through defined interfaces and are not a subject of this deliverable. Any updates to standards, regulatory requirements, or partner systems that materially affect the design will be captured through the project's implementation tasks and reflected in subsequent deliverables or revisions as appropriate.

2. BACKGROUND ON DSO'S & LOCAL ENERGY GRIDS.

2.1. Milano – Unareti

Unareti is a key player in Italy's energy distribution sector, born from the consolidation of network services within the A2A Group. Its origins trace back to the integration of multiple local utilities, aiming to create a unified entity capable of managing electricity and gas distribution across strategic areas in Northern Italy. Over time, Unareti has grown into a robust infrastructure operator, serving major urban centers such as Milan and Brescia, as well as numerous smaller municipalities. Today, the company employs over 1,500 professionals, and manages services for over 65 municipalities, ensuring high standards of efficiency, safety, and sustainability. Its governance model emphasizes ethical responsibility and environmental leadership, aligning with Italy's regulatory framework and European decarbonization goals.

2.1.1. Grid characteristics

As a Distribution System Operator, Unareti plays a pivotal role in Italy's energy transition. It is responsible for the integrated management of electricity and gas distribution networks, regulated by "Autorità di Regolazione per Energia Reti e Ambiente" (ARERA, the Italian regulatory body for electric grids) to guarantee neutrality, transparency, and service quality. Unareti is actively investing in smart grid technologies, including the rollout of second-generation smart meters and advanced substations, to enhance grid flexibility and resilience. The company is participating in European initiatives like AHEAD and SENERGY NETS, which focus on AI-driven grid planning and flexibility services. These efforts position Unareti as a leader in enabling electrification, integrating renewable energy, and supporting local energy communities, making it ready for Italy's sustainable energy future [1].

Table 1: Milano Grid Information

Metric	Value
Total grid length	14,487 km
MV grid length	5,677 km
LV grid length	8,810 km
Cable vs. overhead	78.6% underground
Grid topology description	radial
Number of MV/LV substations	9,376
Number of transformers	9,466
Typical transformer ratings	250, 400, 630 kVA
Nominal voltages (kV levels)	Mainly 10kV & 20kV (MV), 230V (LV)
Power losses	3.56%
Redundancy level	92% of MV/LV transformers

2.1.2. SCADA/ADMS/AMI availability

The grid is supervised in real-time, including MV-level voltage monitoring, and is coordinated through Schneider Electric's ADMS. A central Distribution Management System (DMS) doubles as SCADA, consolidating alarms, events, and trend data with dedicated operator views. Remote switching capability is fully deployed at primary substations (100%) and partially at secondary substations (36%).

Substation automation levels vary across primary sites; medium-voltage breakers are equipped with auto-reclosing capabilities using an active cycle. Advanced metering infrastructure (AMI) covers 91.9% of customers.

The Advanced Distribution Management System (ADMS) is the integrated management system that supports Unareti in the planning process. Among the various functionalities available in this tool, there is the possibility of analysing the load conditions in the different grid portions to identify congestions, plan grid expansion, and estimate future needs due to the evolution of the load. This tool supports Unareti for planning, operational planning, and real-time grid operation.

Operational planning oversees the short-term operation of the grid to address grid criticalities before they occur. This can be done thanks to the grid reconfiguration ADMS tool, the setup of the on-field technicians' workload, and the analysis of the status of the grid's health.

The real-time operation of the grid is conducted by the control room, which consists of functionalities that allow continuous monitoring of the state of the grid and enable timely decisions in the event of emergencies or critical situations this is supported by the SCADA system of the ADMS. This is possible thanks to over 30% of secondary substations being remotely monitored and controlled by a fibre optic communication system. All primary substations are equipped with protection devices that communicate among themselves and with the Protection devices installed on 15% of the secondary substations. Thanks to this, the control room can remotely control the MV grid and locate the faulted portion of the grid using the remote-controlled secondary substation and counterfeed the feeders not affected by the fault.

In addition, within the Unareti grid, it is possible to identify "Automation Clusters" that have the objective of selecting and isolating the faulted portion of the grid, thereby enhancing the system's self-restoration. These clusters are made possible thanks to the protection systems, installed in each primary substation and in the relevant secondary substation, which interact through the fibre optic communication system. The protection systems communicate through the IEC 61850 protocol promptly detecting fault occurrences and implementing suitable countermeasures. This is managed automatically without the need for intervention from the control room operators.

2.1.3. Consumption Patterns and Load Profiles

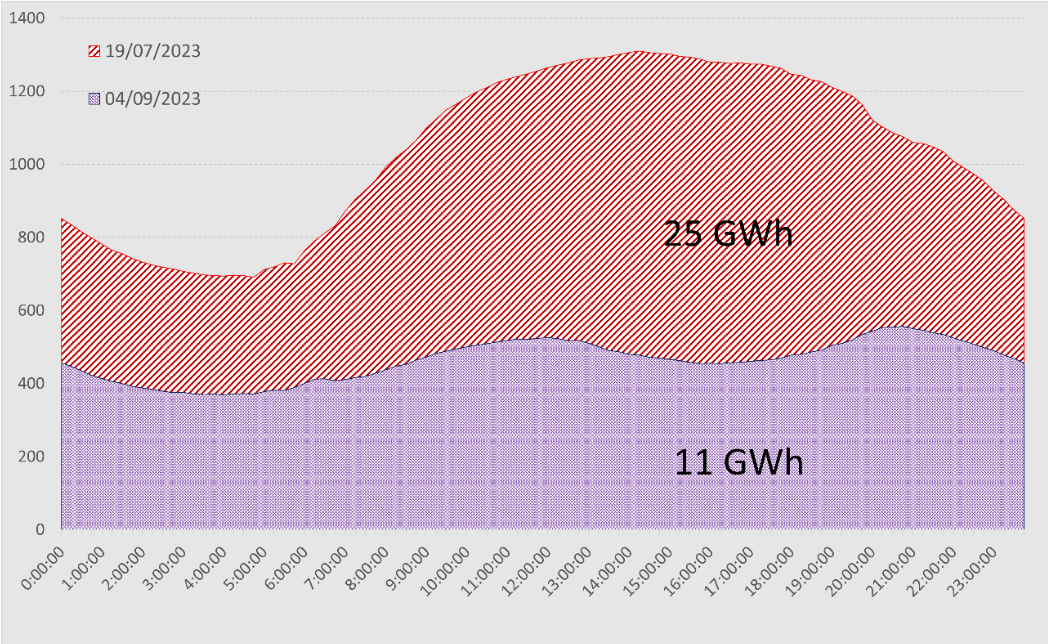

Figure 1: Milan area typical daily consumption patterns.

In the Milan area, demand follows pronounced daily and seasonal swings linked to urban activity and climate, with identifiable minimum and maximum days captured by the DSO's standard "typical curve" set as shown in Figure 1. The sectoral split is 80% domestic use and 20% commercial/industrial. Distributed generation remains modest in Milan (5% PV/DER penetration), while the wider Unareti territory shows higher levels in Brescia (55%). System peaks reported for 2023 are approximately 1,752 MW for Milan and 372 MW for Brescia, providing the reference envelope for planning and flexibility assessments.

2.1.4. Mobility and Traffic Data

Milan's ATM (Azienda Trasporti Milanesi) has a plan to completely electrify its bus fleet by 2030. The plan involves converting all 1,200 buses to electric, with 282 electric and approximately 300 hybrid buses already in use as of 2025. Plans are to expand to 619 units by the end of 2026. New or converted depots are being equipped to support full-electric fleets, each with a capacity for about 150 electric buses. At present, five depots (San Donato, Sarca, Giambellino, Palmanova, and Monza) host the electric fleet, maintaining a one-to-one ratio between chargers and vehicles. Depot chargers typically provide 100 kW DC power. In addition, e-buses can be charged outside depots using opportunity charging stations. Currently, 18 high-power charging points are available across four strategic locations in Milan. These stations deliver up to 200 kW of DC power, allowing for faster charging and minimizing downtime during operations. However, these systems currently operate without integration with the DSO, and recently innovative agreements are being put in place (e.g., for the San Donato depot) to enable flexible, demand-following charging profiles that align with grid availability. The total additional power required for bus charging is estimated at ~100 MW.

As of June 2024, Milan has 912 public charging stations with a total installed power of about 29.8 MW. The majority (43%) are “accelerated” (7.4–22 kW), and 22% are ultra-fast (>50 kW). The annual energy consumption for public charging is about 12 GWh. Private charging points are not quantified in the document; however, the city expects a significant increase in both public and private installations to support the projected 180,000 EVs by 2030.

2.1.5. Data Availability

Unareti’s operational technology stack combines a centrally operated ADMS, consolidating alarms, events, trends, and operator views, with wide but uneven field telemetry. Remote switching is fully deployed at primary substations (100%) and available at a subset of secondary substations (36%), while voltage measurements are sent by only a small number of MV/LV transformers. Advanced metering infrastructure covers 91.9% of customers; however, dataset granularity, export formats, and long-term retention policies are not formally specified. Forecasting relies on external weather feeds and supports real-time estimation of load and production, with contract power per customer used as a key input. For planning and integration studies, Unareti is developing a hosting-capacity (HC) tool based on pandapower. Current bottlenecks are primarily line overloading and congestion, exacerbated by summer air-conditioning, on MV/LV feeders. Available customer data typically follows 15-minute intervals for power/energy. Data sharing requires explicit end-customer consent, and no standardised data retention is defined.

2.2. Kranj – Elektro Gorenjska

2.2.1. Grid topology, voltages, asset age and condition

Elektro Gorenjska is one of 5 DSOs in Slovenia and is in the North-West of the country. Through active participation in international research and development projects, EG persistently builds the reputation of an innovative reliable partner. Participation in projects like AHEAD enable EG to successfully integrate state-of-the-art technology systems that provide appropriate demonstration environments, important for the implementation and evaluation of new concepts of managing and operating distribution networks.

Table 2: Kranj Grid Information

Metric	Value
Total grid length	5,520 km
MV grid length	1,717 km
LV grid length	3,697 km
Cable vs. overhead	72.29% MV cables, 88.63% LV cables
Grid topology description	radial LV and MV with open loops
Number of MV/LV substations	1,605
Number of transformers	1,854
Typical transformer ratings	400kVa
Nominal voltages (kV levels)	20kV (MV), 110kV (HV), 230V (LV)
Power losses	3,37%
Redundancy level	87% of MV/LV transformers

2.2.2. SCADA/ADMS/AMI availability

Real-time monitoring is in place for HV and MV, with no coverage for LV. Voltage monitoring is implemented at primary transformer stations, and power-quality measurements are present on approximately 70% of MV/LV transformers. Remote switching is available on the MV grid for around 65% of MV/LV transformers, and alarm/event management includes power, voltage, current, and harmonics across distribution equipment.

Substation automation is advanced on a substantial portion of the fleet: All MV/LV transformer stations are connected to SCADA, with 65% of them with remote control capability. The utility is currently transitioning to Schneider ADMS. Smart Meter coverage is approximately 94%, primarily utilizing Power Line Communication (PLC) technology, with about 6% of customers utilizing Point-to-Point Communication (P2P).

2.2.3. Consumption Patterns and Load Profiles

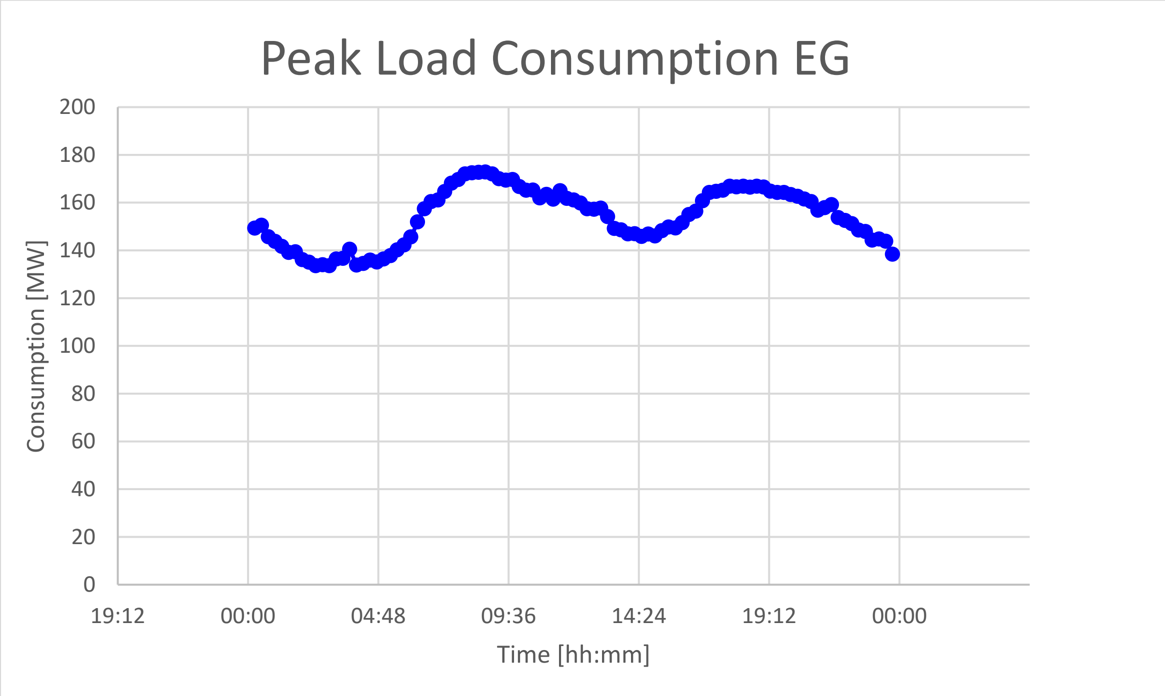

Figure 2: Elektro Gorenjska peak typical daily consumption patterns.

Elektro Gorenjska's load is driven by a mixed residential and commercial base with a significant industrial presence, the typical daily peak consumption is shown in Figure 2. The service area comprises approximately 81,871 residential customers and 10,963 commercial customers (industrial customers are also present but not enumerated here). Renewable integration is significant, with roughly 23% RES penetration contributing to daytime variability and local LV constraints where PV is concentrated. The system's peak demand is on the order of 200 MW (15-minute average measurements), which, together with the customer mix and RES share, presents the operating range for forecasting, hosting-capacity analyses, and flexibility use cases (UCs).

2.2.4. Mobility and Traffic Data

Elektro Gorenjska's transport electrification is still in an early, uneven phase: rail services are electric, but bus electrification is limited to main cities (city traffic), and the charging backbone for transit remains underdeveloped, with only five known bus-charging locations in the city of Kranj. Heavy-duty transport (HDT) is not yet electrified—the DSO area currently has zero dedicated HDT charging points—though a planned 20 MWp charging park signals an intention to serve trucks near the highway in the short term. Across the territory, the broader EV charging landscape appears modest, with an estimated 150 public chargers and an unknown number of private household charging points. Smart charging is not supported by the DSO; instead, charging operations are handled by separate Charge Point Operators (CPOs), and there are no DSO-side scale-wide charging control strategies in place. To date, the utility reports no EV-related grid issues, and no specific integration or coordination schemes with the wider energy system have been stated, underscoring that electrified mobility is present but still largely unmanaged from the grid operator’s perspective and poised to grow from a low baseline.

2.2.5. Data Availability

Elektro Gorenjska’s operational technology software includes SCADA/ADMS supervision with alarms and events for power, voltage, and current across distribution equipment, complemented by remote switching telemetry available on both LV and MV. Voltage measurements are implemented at primary substations, and secondary substations have a high degree of real-time coverage. There are 40% of smart meters that also measure and send per-phase voltage measurements at 10-minute intervals. Forecasting capabilities are not in place and neither load nor real-time forecasts are produced. For grid planning, the utility performs static hosting-capacity (HC) calculations on the LV grid using an internally developed HC algorithm alongside the national legislation on the technical approval of the RES integration. Current bottlenecks primarily occur in LV, associated with the integration of RES (household PV). The challenges mainly revolve around voltage and current problems on LV lines. Data granularity is 15-minute intervals for the customers who own a smart meter, but with availability at *t-1* day. By national law, retention is limited to a maximum of two years, after which data must be deleted. Any data sharing occurs only with explicit approval from end customers.

3. DEMONSTRATOR DESIGN CONCEPT - MILANO.

3.1. General overview of the Demo Site

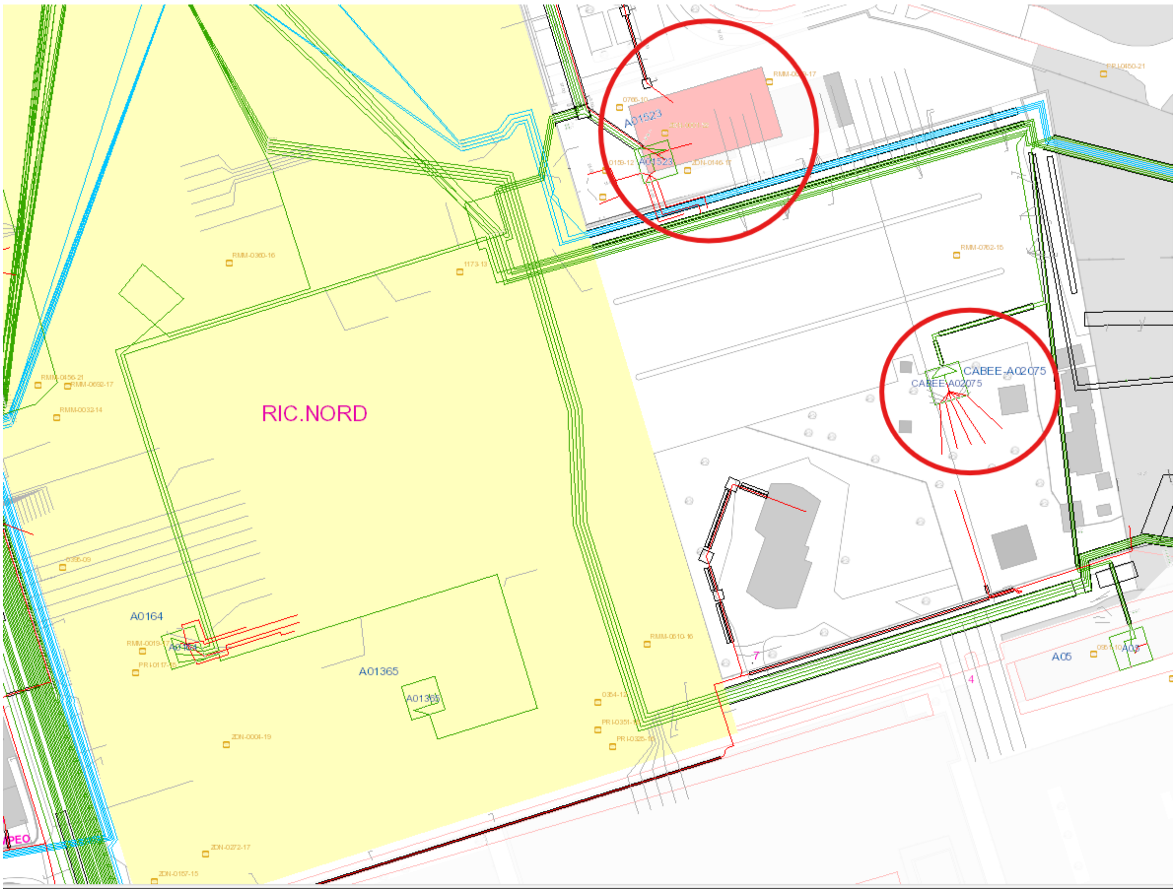

Figure 3: GIS Overview of the planned demo site in Milan, Via Ponte Nuovo. Encircled are the two options of placing the charging station.

The Milan demo test site is in the parking area of a primary HV/MV primary substation in Milan, Italy. This site serves as a charging hub equipped with both fast and slow electric vehicle (EV) charging stations. These stations support the operational and maintenance fleet used for grid servicing, as well as vehicles used for corporate car sharing. Currently, the site features 37 twin-socketed charging stations: 27 are single-phase 3.6 kW chargers, while 10 are wallboxes. Among the wallboxes, 8 are single-phase, 3.6 kW, and the remaining two are three-phase, 22 kW.

3.2. Use Case testing

The Milan demo focuses on Use Case 6, "Smart Charging at Depots," which focuses on optimising the charging of electric buses and HDVs at depot locations, with the goal of improving grid efficiency and reducing operational costs. The main stakeholders involved are the Distribution System Operator, the Public Transport Operator (PTO), and the Charging Equipment Supplier.

The scenarios tested will range from traditional uncoordinated charging (business as usual) to smart charging and vehicle-to-grid (V2G) integration. The testing will include monitoring energy consumption, charging station utilisation, and grid impact, with KPIs such as charging cost savings, energy discharged to the grid, and charger utilisation. The test design will involve scenarios covering business-as-usual charging, optimised charging, and V2G-enabled operations, with data collection and analysis having traceability to AHEAD objectives. A more detailed Use case analysis can be found in the deliverable D1.4 of AHEAD project [2]. Table 3 shows the Use Cases and the represented specific use cases that will be tested in WP8.

Table 3: Milan use case description

UC NR.	Use Case description	Objectives	Specific use case tested in WP8
UC1	New DR and flexibility contracts	Test new demand response programs and flexibility contract models	SUC1.2
UC2	Charging station with low rated capacity	Demonstrate smart charging strategies under limited grid capacity	SUC2.2
UC3	Cyber security charging platform	Improve cybersecurity resilience of EV charging infrastructure	SUC3.2
UC4	Novel charging technologies	Demonstrate heavy-duty and bus charging	SUC4.3
UC6	Smart charging at depots	Demonstrate the benefit of bus fleet management and its implication in the MV grid	SUC6.1
UC9	Coordinated charging via CPOs	Test coordinated charging strategies implemented by CPOs	SUC9.3
UC11	Activation of flexibility services by DSO	Operational activation of flexibility services by DSOs using advanced control and decision-support tools.	SUC11.3
UC12	Grid planning with AI tools	Apply AI-based planning and forecasting tools.	SUC12.2

3.3. Functional Requirements for the Demo Site

3.3.1. Data acquisition

The involvement of multiple stakeholders (DSO, CPO, and public transport operators) necessitates robust data sharing and interoperability, facilitated by protocols such as Open Charge Point Protocol (OCPP) and secure communication networks.

3.3.2. Communication & Interoperability

Standardised communication protocols, such as OCPP for charger interaction and IEC 61850 or similar for grid integration, are required to facilitate interoperability between equipment from different manufacturers and to enable smooth coordination of charging and Vehicle-to-Grid (V2G) activities. The platform must also support secure API connections for both internal and external integration, with authentication and authorisation mechanisms in place to protect system integrity and data privacy.

3.3.3. Control & Optimisation

The control and optimisation framework is designed to maximise grid efficiency while maintaining service quality for the electric buses. At its core, the system plans to employ scheduling and optimisation algorithms that dynamically assign charging profiles based on real-time data, including energy demand, grid constraints, vehicle SoC, and operational schedules. The charging management system will collect and process this data, executing control strategies that minimise peak loads, reduce operational costs, and support grid stability. For the V2G testing, the control logic extends to bidirectional power flows, activating discharge events in response to DSO requests for grid support during periods of high demand or grid congestion. These optimisation routines will be continually refined using historical and real-time data, ensuring that charging and discharging events are always aligned with grid needs and operational priorities.

3.3.4. Monitoring

Key performance indicators, including energy consumption, peak reduction, and energy shifted, will be tracked, calculated, and stored within the monitoring platform. This system will collect data from field devices, charging stations, and the SCADA system, providing visibility into charging operations and the impact on the grid. All monitoring data will be logged for analysis and review via dashboards and reporting tools, supporting both operational oversight and long-term performance evaluation.

3.4. Technical Architecture

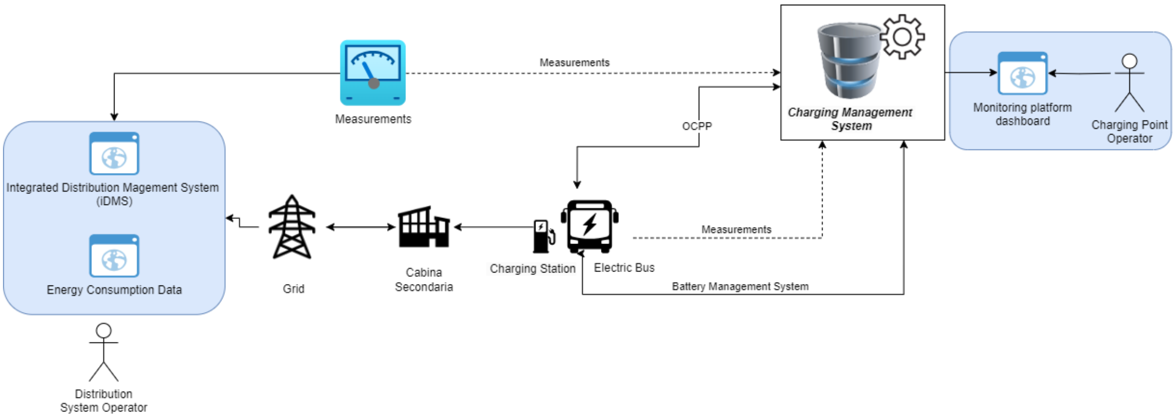

Figure 4: Technical schema of the demo site.

3.4.1. Hardware

A new 100 kW Vehicle to Grid (V2G) charging station consisting of a Power Unit and a Satellite Unit is planned for installation. The charger will be installed right outside the secondary cabin, which has been designated as the setup location for the charging infrastructure. This area includes sufficient space for both the installation of the charging stations and the parking of buses and setting up the battery for simulation. The proposed technical architecture/schema of the demo site is show in Figure 4.

3.4.2. Software

The software that will be used already exists in the Distribution Management System (DMS) and will be complemented with the tools developed in WP4 and WP6 as the project progresses. Apart from this, a charging management system is planned to be incorporated to collect data from the EV charger and, based on the smart charging optimization algorithms, provide charging schedules that optimize the charging process.

4. DEMONSTRATOR DESIGN CONCEPT - KRANJ.

4.1. General overview of the Demo Site

The Kranj demonstrator is located at the Arriva bus depot in the city of Kranj, a mixed residential–industrial urban setting with direct access to regional transport corridors and proximity to Elektro Gorenjska headquarters. The depot lies within the supply area of the Primskovo 110/20 kV primary substation, which provides the medium voltage (MV) source for the site’s existing and planned charging infrastructure. Protection coordination follows standard DSO practice on the MV side with customer-side protective devices and interlocks at the transformer and LV distribution levels. GIS overview of the planned Kranj location is shown in figure 5.

At the time of writing, the site hosts four electric bus charging stations that are already in service, used by one of the largest Slovenian bus operators, which provides urban, suburban, and intercity transport. An HDV charging depot is planned for implementation at the same location, with a total installed charging capacity of up to approximately 20 MW, phased to align with grid capacity, land use permitting, and operational readiness.

Communications on site are expected to combine standards-based EV management and secure telemetry. Charger backends will utilize OCPP (v1.6J or 2.0.1, as available) for session control, metering data, and power setpoint commands, with the protocol version and feature profile verified per vendor. Organisationally, EG acts as the DSO and site integration lead for grid-side interfaces and constraints. Arriva provides depot access, operational schedules, and fleet requirements. The complete Kranj demonstration concept will be simulated within the AHEAD project, where solutions developed in WP3, WP4 and WP6 will be tested to assess the impact of HDV charging concept on the DSO grid.

The operational baseline will be established using a combination of historical SCADA data from Primskovo MV feeders (where available) and AMI at the depot. Baseline metrics will quantify percentile P95/P99 feeder and LV loading. This baseline provides the reference against which smart charging and UCs will be evaluated in Section 4.2.

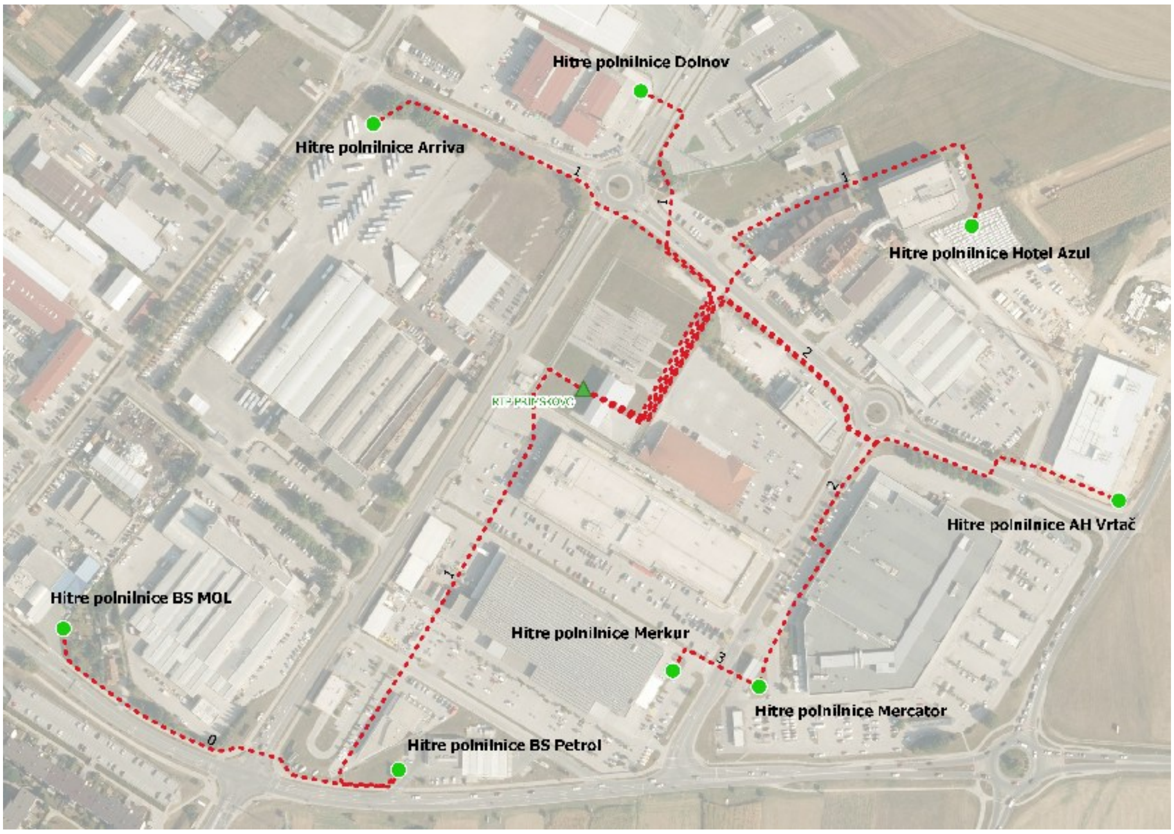

Figure 5: GIS overview of the planned demo site

4.2. Use Case testing

At the Arriva Kranj depot supplied from the Primskovo 110/20 kV substation, the demonstration will test **UCs 1–4, 6, 9, 11, and 12**, namely, demand-response and flexible-capacity contracts, operation of charging stations under constraints, smart charging at depots, coordinated charging via CPOs, DSO activation of flexibility services, and grid planning with AI tools. Acceptance will focus on achieving quantifiable improvements, such as feeder/coincident-peak reduction (target ≥ 15%), depot energy-cost savings, charger utilization under constraints, and model accuracy for spatial planning. A more detailed Use case analysis can be found in the deliverable D1.4 of AHEAD project [2]. Table 3 shows the Use Cases and the represented specific use cases that will be tested in WP8.

Table 4: Kranj use case description

UC NR.	Use Case description	Objectives	Specific use case tested in WP8
UC1	New DR and flexibility contracts	Test new demand response programs and flexibility contract models	SUC1.2

UC2	Charging station with low rated capacity	Demonstrate smart charging strategies under limited grid capacity	SUC2.2
UC3	Cyber security charging platform	Improve cybersecurity resilience of EV charging infrastructure	SUC3.2
UC4	Novel charging technologies	Demonstrate heavy-duty and bus charging	SUC4.3
UC6	Smart charging at depots	Demonstrate the benefit of bus fleet management and its implication in the MV grid	SUC6.2
UC9	Coordinated charging via CPOs	Test coordinated charging strategies implemented by CPOs	SUC9.3
UC11	Activation of flexibility services by DSO	Operational activation of flexibility services by DSOs using advanced control and decision-support tools.	SUC11.3
UC12	Grid planning with AI tools	Apply AI-based planning and forecasting tools.	SUC12.2

4.3. Functional Requirements for the Demo Site

Part of the depot is live today, and the rest of the infrastructure, along with some DSO activations, will be exercised in simulation. We therefore run a **hybrid live–simulation setup**: real devices send real measurements, while the missing devices, expanded capacity, and selected signals are provided by the **WP3 simulation engine**. Every dataset clearly indicates whether it is live or simulated, ensuring that results remain comparable.

4.3.1. Data acquisition

EG will collect power, energy, voltage, current, and status from depot points of common coupling (PCC) and any onsite DER. Live and simulated assets follow the same cadence: sampling every 1 minute. All records use the same time base (NTP/PTP), ensuring timestamps align across meters, chargers, gateways, and the simulator. Each data point carries stable IDs for the device, site, and connector, and a flag saying whether it is **live** or **simulated** (and, for simulation, whether time is real-time or replay). Ingestion utilizes a simple, common data model (names, units, schemas) and basic data quality checks to identify gaps, outliers, and unit errors.

4.3.2. Communication & Interoperability

The platform integrates via **REST/JSON** and/or **MQTT**, utilizing published specifications and versioned topics/endpoints. The simulation will exchange data between the different actors (ADMS of the DSO, Grid Flexibility Simulator, and Charging Point Operator). Clients implement sensible timeouts and retry with backoff. The simulator can deliberately return errors or delays, allowing us to test resilience in a safe manner.

4.3.3. Control & Optimisation

A Grid Flexibility Simulator computes limits and sends them to the CPO; during constraint events, it updates roughly every minute, and otherwise every few minutes. If the EV is present, or only in the simulator, the optimizer coordinates charging while keeping SoC, transformer, and feeder limits, as well as fleet readiness, within bounds. Decisions respect DSO dynamic limits and the contract and keep an audit trail of inputs and outputs for later analysis.

4.3.4. Monitoring

The platform calculates the Key Performance Indicators (KPIs) needed for the project, such as peak reduction at the PCC, energy shifted off-peak, and charger utilisation under constraints. Dashboards show simulation status and history. Alerts are raised when thresholds are breached (for example, a PCC rating above 90%). Reports will summarize results and list software versions, key configurations, and simulator parameters, ensuring runs are reproducible.

4.4. Technical Architecture

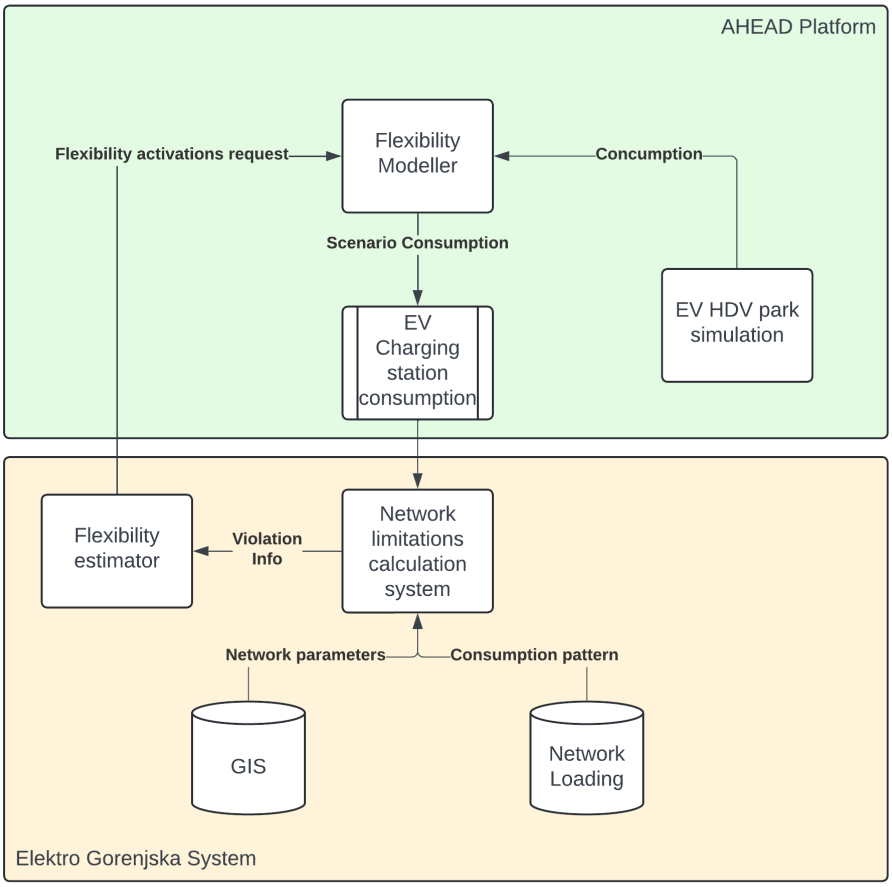

Figure 6: Software schematics of the demo site.

The Slovenian demo focuses on integrating the AHEAD flexibility services simulation with real-time operational data provided by Elektro Gorenjska distribution system as shown in Figure 6.

Real world consumption data from primary substation are used as input to the AHEAD HDV EV charging park simulation, where different flexibility services and control strategies are evaluated. Data from GI and network loading are combined with EV charging station consumption profiles in the network limitation calculation system, which assesses grid constraints and detects operational violations. Detected violations are forwarded to the flexibility estimator, which determines the required flexibility activation and sends flexibility activation request to the flexibility modeller. The flexibility modeller adjusts EV charging behaviour, accordingly, affecting charging station consumption and closing the simulation feedback loop between grid constrains, flexibility activation and EV charging demand.

4.4.1. Hardware

The indicative bill of materials includes the depot MV intake, site transformers sized for phased growth toward the planned charging capacity, LV switchboards with appropriately coordinated protection, DC fast chargers for buses/HDVs (connector/pantograph types and power ratings), class 0.5s (or better) PCC, industrial Ethernet switches and a firewall/router for the OT/DMZ/IT segments. Site layout documents transformer and charger locations, cable routes, and sizing and segregation of LV boards. Currently, we have two live charging stations (each with a capacity of 150kW), and the rest will be simulated.

4.4.2. Software

The software stack comprises: SCADA, which provides the continuous consumption data at the demo site. A Flexibility analysis tool that executes and invokes an EMS that schedules depot charging; the **WP3 simulation engine** that emulates chargers for future installed infrastructure and for activation scenarios; a data platform that ingests, validates, stores, and serves timeseries and session data; dashboards for operators and project partners. Interoperability relies on SCADA consumption and power quality limits.

5. CONCLUSIONS

Deliverable D8.1 defines the design concept, functional requirements, and technical architecture for the Southern Demo across two representative demo sites, i.e., Milano (Unareti) and Kranj (Elektro Gorenjska). The work consolidates the local grid and mobility baselines, clarifies interoperability and control needs for EV charging, and specifies how live systems and simulation will be combined to validate AHEAD UCs in real operational settings.

In Milano, the demo site builds on an advanced SCADA/ADMS environment. The site configuration at the primary substation enables controlled trials of smart charging and, where feasible, V2G, anchored by standardised interfaces (OCPP, IEC 61850 where applicable) and a charging management layer for setpoint dispatch. The emphasis is on congestion management, peak shaping, and operational coordination with the DSO.

In Kranj, the Arriva depot provides a simulation-based, fleet-scale context with a roadmap toward high-power HDV charging. The hybrid approach, i.e., live chargers plus a WP3 simulation engine, allows the consortium to test DSO activations, dynamic limits, and optimiser behaviour before full build-out. This setting is particularly well-suited for testing flexibility under grid constraints and quantifying the benefits.

The main challenges in the near term are related to the setup of demo infrastructure, including timely delivery, installation and commissioning of equipment at the Via Ponte Nuovo site in Milan. This includes the preparation of the required civil infrastructure, such as foundation design and construction, in line with technical requirements and project timelines. An additional challenge is the integration of the AHEAD tools with real-world grid processes and operational data, considering critical infrastructure. These activities are covered under Task 8.2, which focuses on translating conceptual scenarios into operational implementation.

After the infrastructure is installed and connected to the grid, the next steps will focus on the operation and monitoring of the demo setup under Task 8.4 and 8.5. This will be followed by the analysis of results and lessons learned. In parallel, the Slovenian demo will proceed with connecting the AHEAD tools to real-world grid data from GIS and network loading system. This will support further activities within WP8.

6. REFERENCES

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