Implementation of a 2D/3D WebGIS for Electricity Network Management System

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Abstract

Effective planning, management, and optimization of electrical distribution networks are essential components of modern smart city development and energy sustainability. This study presents a geospatial decision-support system for the low and medium voltage (LV/MV) network of Elektrokrajina d.o.o., the main electricity distributor in Republika Srpska. Model of the system is built upon the extended INSPIRE Utility Network – Electricity model. It leverages a 2D/3D WebGIS platform (ELMAP) to visualize, analyze, and manage electrical infrastructure using open-source technologies such as PostgreSQL/PostGIS, pgRouting, Geoserver and Mapbox. The integration of real-time and semi-structured data from sensors and enterprise systems (e.g., SAP, MDM) is enabled via service-oriented architecture and parallelized query execution. Particular attention is given to addressing topological inconsistencies in legacy data, reconstructing network topology, and linking meter positions to buildings using GPS and OSM data. Custom algorithms were developed for voltage-level tracking, meter reading route optimization, and network loss analysis, including indicators such as SAIFI, SAIDI, and peak loads. The platform enables spatial identification of critical infrastructure points and supports strategic decisions regarding transformer zoning, network upgrades, and demand management. This research highlights the importance of structured 3D geospatial data and demonstrates how scalable, open-source WebGIS systems can support the energy sector in meeting smart grid and sustainability goals.

1. Introduction

Recent advancements in Urban Digital Twin (UDT) technologies and the widespread adoption of Internet of Things (IoT) have transformed how urban infrastructures are monitored, analyzed, and managed. UDTs create real time links between geospatial models and their physical counterparts, enabling dynamic interaction with 2D and 3D spatial data, enriched by sensor inputs. While some proprietary platforms have demonstrated early UDT applications, open source, web based geospatial systems capable of real-time infrastructure monitoring remain limited (Vassena et al., 2023).

In parallel, distribution network planning a key aspect of urban infrastructure requires multi criteria assessment frameworks that incorporate not only technical and economic factors but also disaster resilience and regional context. This necessitates systems capable of integrating spatial, environmental, and infrastructural data to support smarter decision making process (Zhang et al., 2022).

This paper presents the architectural model and implementation of ELMAP, WebGIS based system for visualizing and managing the power distribution network of Elektrokrajina a.d. built on open source technologies (PostgreSQL/PostGIS, GeoServer, Mapbox). The system integrates geospatial layers of electricity network architecture, real time meter readings (AMM), and enterprise systems (SAP, MdM). It lays the foundation for a scalable and modular platform aligned with UDT principles, enabling future integration of real time monitoring, risk assessment, and predictive planning tools.

2. Related works

The increasing complexity of urban energy distribution networks and the growing demand for sustainable and efficient energy management have necessitated the development of advanced geospatial frameworks that integrate real-time monitoring, 3D visualization, and analytical processing. Urban Digital Twins (UDTs) have emerged as a powerful extension of traditional Digital Twin concepts, allowing for the synchronization of 3D spatial data with real time sensor inputs to better represent and manage urban environments. Several studies have explored how lightweight, open source frameworks can connect building scale 3D models with sensor data streams enabling fine grained monitoring and simulation of infrastructure behavior.

Present frameworks that combine HTML5, WebGL, and CityGML models for real time representation of city scale infrastructure have been developed in the context of 3D geospatial web visualization (La Guardia et al., 2024; Biljecki et al., 2021). These implementations focus specifically on semantically rich digital twins for power networks. While these approaches demonstrate significant progress in visualization and data integration, they often lack domain-specific modeling components such as semantic energy attributes and connectivity based loss propagation which are crucial for electrical distribution systems. Furthermore, although INSPIRE compliant models serve as a foundational reference for harmonizing geospatial utility data in the European context, there remains a notable absence of standards tailored to smart grid components or near real time telemetry. This creates a research gap around extending these data models to reflect both the temporal dynamics and operational complexity of energy infrastructure, especially in smart city settings (Table 1).

Domain	Contribution	Key references	Research gap
3D Visualization & Digital Twins	Real-time 3D UDTs using WebGL and HTML5 for urban infrastructure monitoring	La Guardia et al. (2024), Vassena et al. (2023), Biljecki et al. (2021)	Lack of domain-specific UDTs for power networks with semantic energy data
Power Loss Tracking	Heuristic planning for underground networks, multi-criteria loss assessment	Zheng et al. (2012), Villacres & Inga (2019)	Real-time loss visualization with integrated GIS and AMR/SCADA missing
INSPIRE Model Extension	Harmonization of electric infrastructure data within EU SDI	INSPIRE TWG (2013), Sliškov et al. (2020), Kreutz et al. (2015) Amović et al. (2021)	No standard for smart grid components or near real-time telemetry
Parallel Processing	CPU/GPU and distributed computing for power simulations	Shi et al. (2018), Zhuang et al. (2015), Wang et al. (2021)	Limited use of hybrid parallelism in 3D web-based geospatial platforms
Map Rendering & vGPU	Comparison of rendering engines; Mapbox optimizations with vGPU	IJGI (2019), González et al. (2020), Mapbox Docs, NVIDIA vGPU Quantifying the Impact of Virtual GPUs.	WebGL performance scaling with dynamic 3D geospatial datasets still challenging

Table 1. Summary of Related Works and Research Gaps of the WebGIS for Electricity Network Management System.

From an analytical perspective, spatial simulation and geospatial analysis techniques have been used to assess energy losses and improve network planning. Multi criteria decision making approaches in distribution planning, incorporating factors like regional vulnerability and disaster resilience, have been emphasized in previous research (Zheng et al., 2012). However, many of these analyses rely on static datasets and rarely leverage the spatiao-temporal potential of real time GIS and SCADA systems. Integrating such data into interactive 3D platforms opens opportunities for improved fault detection, anomaly mapping, and loss minimization, especially when they are paired with adaptive visualization strategies and distributed processing.

In terms of system performance and scalability, advances in GPU and cloud computing have enabled substantial improvements in real time rendering and parallel analytics. The feasibility of hybrid CPU-GPU workflows in high volume energy simulations has been illustrated in previous research, yet few of these solutions have been applied in web-based 3D geospatial environments (Wang et al., 2021; Shi et al., 2018; Zhuang et al., 2015). he need for scalable, GPU-accelerated frameworks becomes even more apparent in rendering intensive applications like 3D infrastructure monitoring, as demonstrated by studies comparing the performance of open source web mapping libraries and identifying Mapbox GL JS as superior in interactive vector data scenarios (González et al., 2020; Lin, 2019). This insight is supported by NVIDIA's vGPU performance evaluations (NVIDIA Development Team, 2019), which highlight the advantages of virtual GPU infrastructures in terms of rendering speed and user responsiveness as key factors when multiple users interact with large scale geospatial datasets simultaneously.

Complementing the technical and analytical components, recent studies have emphasized the challenges of managing urban geospatial big data within smart cities. There is a need for efficient data integration strategies and modular system architectures to cope with the high volume, variety, and velocity of sensor and geospatial data (Amović et al., 2021). This findings support the push toward more holistic urban platforms that combine spatial data infrastructures, IoT integration, and advanced analytics, an approach well aligned with the development of spatially enabled UDTs for complex spatial data management.

Together, these contributions reveal a multidimensional research and implementation landscape where 3D web visualization, distributed computing, and standardized spatial modeling converge. However, despite substantial progress in each individual domain, there is a noticeable lack of integrated, opensource platforms that synthesize these technologies into coherent solutions for real time energy monitoring. Bridging this gap requires the development of modular, scalable systems that incorporate 3D rendering engines, INSPIRE aligned utility models, GPU virtualization, and live telemetry all tailored to the operational and analytical demands of power distribution networks in modern cities.

3. Case study

Municipality of Srbac (Figure 1) was selected as the case study location due to its manageable spatial extent, availability of utility network documentation, and prior collaboration on GIS based infrastructure projects. Although the municipality has not formally adopted a Smart City agenda, the implementation of a pilot 3D WebGIS platform for monitoring energy infrastructure represents a significant step toward modernizing utility management.

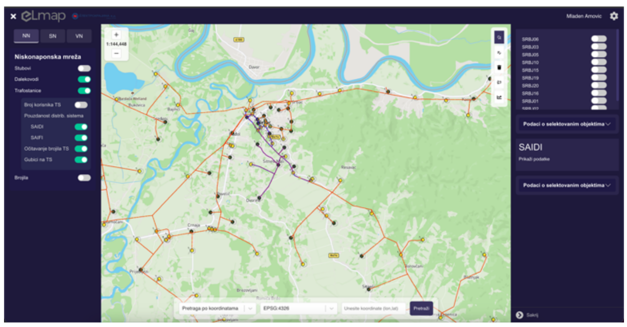

Figure 1. LV/MV power distribution network.

As part of the project, existing geospatial data, cadastral plans, technical layouts of the power distribution network, and terrain models were harmonized and integrated into a PostgreSQL / PostGIS database. Using FME for ETL processes and QGIS for initial processing (used for reverse geocoding), a semantic 3D model of the distribution system was developed. This model served as the foundation for a web based visualization interface built with Mapbox GL JS, enabling real time status tracking and spatial querying of electrical assets. The system architecture allows for scalable deployment, with rendering supported via virtualized GPU environments. While full integration with SCADA systems remains a future goal, simulated status data was used to test interactive analytics functions and spatial filtering capabilities.

Srbac's case demonstrates the feasibility of lightweight, open source geospatial platforms for small municipalities with limited technical resources. It also highlights ongoing challenges such as incomplete data records, lack of real time telemetry, and the need for standardized modeling of low/medium voltage (LV/MV) networks. Nonetheless, the pilot laid a practical foundation for future expansion toward more advanced spatial energy monitoring tools.

4. Methodology for data acquisition and processing

The development methodology of the ELMAP system for planning and managing the LV/MV power distribution network is structured as a multi phase, layered process (Figure 2.). It begins with the analysis of the INSPIRE Utility Network Model and the ISO and OGC standards relevant to the domain (Lemmens and van Oosterom, 2017., ISO 19109:2015).

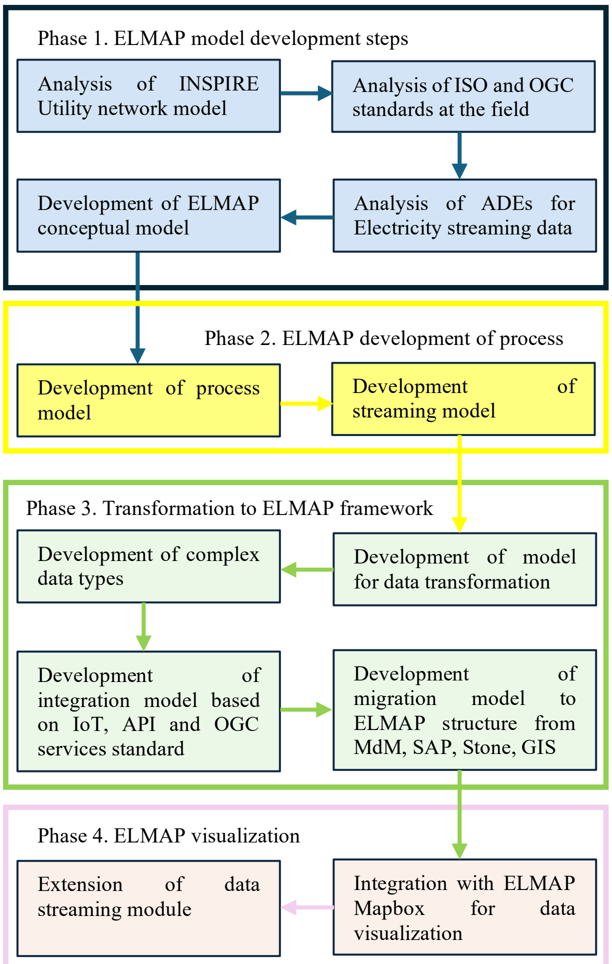

Figure 3. Roadmap of ELMAP system.

Simultaneously, the conceptual model of ELMAP is developed, followed by an analysis of ADEs (Application Domain Extensions) for the electricity streaming data model (Kutzner et al, 2020.). These foundational activities ensure compliance with international geospatial and utility modeling frameworks (Schade and Craglia, 2013.).Based on these analyses, the methodology proceeds with the development of two parallel models: the process model, which captures business logic, workflows, and system operations; and the streaming model, which handles dynamic data flow related to electricity consumption and losses (Figure 3.). These two models act as the backbone for structuring the data and system behavior.

Subsequently, the focus shifts to definition of complex data types and the development of a model for data transformation, ensuring that data coming from various sources can be harmonized and structured. This is essential for achieving semantic and syntactic interoperability across different subsystems.

In the next step, a data integration model is established using IoT, API, and OGC services, providing the infrastructure for communication between devices, databases, and services (Ali et al., 2021). In parallel, a system integration model is built to map and transform data from external systems such as SAP, MdM, Stone, and GIS platforms into the unified ELMAP model (Figure 4.). This allows the aggregation and processing of both structured and semi structured data, including geodetic and metering results.

Once the foundational models are established and integrated, the system is extended with a streaming data module, which supports real-time input and processing of electricity data. In the final step of the methodology, this module is integrated with ELMAP and the MAPBOX platform for 3D data visualization, allowing the system to present geospatial and temporal electricity data in a comprehensible visual format. All infrastructure components, including poles, lines, transformer stations, and meters, are visualized as GLB assets and optimized using 3D Tiles to ensure efficient rendering of large scale data (Gröger et al., 2012; Zhao and Yao, 2017). This holistic and layered methodology ensures that the system is not only compliant with international standards but also optimized for high performance, accurate modeling, and real-time decision support, as shown by the vertical and horizontal integration steps illustrated in the provided diagram.

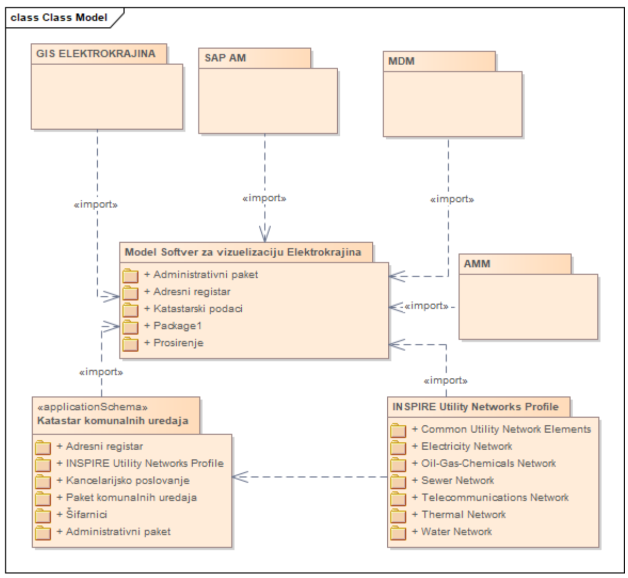

Figure 4. Package diagram of ELMAP system.

4.1 Automation and topological enforcement

ELMAP system has ability to maintain strict topological consistency across hierarchical spatial entities, specifically segment, section, and line, in both 2D and 3D contexts. This consistency is crucial for ensuring reliable spatial analysis, navigation through the network model, and rendering precision during visualization (Zhou and Kapoor, 2011; Iovan et al., 2013.). The system automates multiple stages of data processing and validation to enforce this consistency. The following Table 2. summarizes the main automation procedures involved in maintaining data integrity and spatial relationships.

Automation Stage	Description	Technology Used	Output
Geometry snapping and alignment	Ensures that each segment endpoint aligns precisely with its neighbors.	PostGIS Topology, Python scripts	Clean node-to-node geometry
Hierarchical linking	Each segment is assigned to a section, and each section to a line.	PostgreSQL triggers + spatial joins	Relational integrity
3D extrusion and vertical alignment	Segments are extruded to 3D using Z-coordinates from survey data or DEM.	Python + PostGIS	Accurate 3D lines and models
Segment continuity validation	Checks that consecutive segments form continuous polylines.	PostGIS ST_Line Merge, ST_Union	Topological correctness
Attribute inheritance	Metadata (e.g., conductor type, voltage) flows from line to segment.	SQL views + automated rules	Metadata consistency
Geometric simplificati on for 3D streaming	Reduces 3D complexity for WebGL rendering, retaining spatial accuracy.	glTF export pipeline	GLB-optimized 3D models

Table 2. The automation and topological enforcement within the ELMAP system.

The topological structure relies on ensuring that each segment (lowest unit) is:

- Snapped to both preceding and following segments to avoid gaps or overlaps,
- Properly connected to its parent section (dionica) through foreign keys and validated spatial joins,
- Vertically aligned using elevation data, preserving Z-geometry for 3D modeling and network continuity,
- Consistent in direction, using consistent digitization and orientation (e.g., from source to sink).

In 2D, topology is enforced using PostGIS geometry constraints (ST_IsValid, ST_Relate), while in 3D, additional validation steps include vertical alignment (Z-continuity) and extrusion tests to ensure models are properly represented in .glb format for rendering. A hybrid approach is used where the 2D base geometry is always authoritative. From this, the 3D geometries are derived by applying a height model or predefined Z-values. This approach simplifies update workflows when a 2D geometry is updated, a trigger recalculates the corresponding 3D representation.

4.2 Parallel processing algorithm

The ELMAP platform, designed for spatially enabled utility asset management, incorporates a robust mechanism for handling asynchronous data ingestion from external sources such as electric meter readings. A key challenge addressed in this system is the conditional and delayed integration of new data in a way that prevents redundancy, maintains referential integrity, and supports near real time updates to the central geospatial registry of metering points (mjerna_mjesta). To manage the influx of data, particularly when it arrives in batches from external CSV uploads or field sensors, ELMAP leverages a combination of database triggers and conditional processing functions. When new rows are inserted into the staging table p_ocitanja_brojila_csv, a BEFORE INSERT trigger (trg_update_last_insert_time) is fired, calling a lightweight function to timestamp the entry:

```
CREATE OR REPLACE FUNCTION
update_last_insert_time()
RETURNS TRIGGER AS $$
BEGIN
    NEW.last_insert_time := now();
    RETURN NEW;
END;
$$ LANGUAGE plpgsql;
```

This mechanism records the moment of each insertion, creating a temporal reference point used to detect recent activity in the table. This is crucial for ensuring that follow up processes are only executed after a certain period of inactivity, thus avoiding conflicts caused by overlapping insert and processing operations. A guard function (check_and_process_ocitanja) queries the last_insert_time and proceeds with data integration only if no insert has occurred in the last 10 seconds:

```
CREATE OR REPLACE FUNCTION
check_and_process_ocitanja()
RETURNS void AS $$
DECLARE
    last_insert_time timestamp;
BEGIN
    SELECT MAX(last_insert_time) INTO
last_insert_time
    FROM public.p_ocitanja_brojila_csv;
    IF last_insert_time IS NULL OR
last_insert_time < now() - interval '10
seconds' THEN
        PERFORM process_ocitanja();
    END IF; END; $$ LANGUAGE plpgsql;
```

This debounce like approach ensures efficient batch processing by consolidating multiple rapid inserts into a single processing event, thereby improving performance and data integrity. The core of the data integration logic is encapsulated in the delayed_insert_missing_eic() function, which performs a conditional insert of Electric Identification Codes (EICs) from the processed data table p_ocitanja into the reference table mjerna_mjesta, for those EICs that do and do not already exist. If recent insert activity is detected, the function temporarily sleeps before proceeding:

```
CREATE OR REPLACE FUNCTION
delayed_insert_missing_eic()
RETURNS void AS $$
BEGIN
    IF (SELECT MAX(last_insert_time) FROM
public.p_ocitanja) > now() - interval '10
seconds' THEN PERFORM pg_sleep(10); END IF;
```

```
    INSERT INTO public.mjerna_mjesta (eic,
kupac, tip, naziv, ...
        , geometrija) SELECT po.eic,
        TRIM(SUBSTRING(po.kupac        FROM
POSITION('-'  IN  po.kupac)+1))  AS  kupac,
'potrošač',
        TRIM(SUBSTRING(po.kupac        FROM
POSITION('-' IN po.kupac)+1)) AS naziv,
        ...
    FROM public.p_ocitanja po
    JOIN public.mjerna_mjesta mm ON po.eic
= mm.eic
    WHERE  NOT  EXISTS  (  SELECT  1  FROM
public.mjerna_mjesta mm
        WHERE  mm.eic  =  po.eic  );  END;  $$
LANGUAGE plpgsql;
```

This function demonstrates several important implementation patterns:

- Selective Insertion: Only single EICs and missing EICs are inserted, avoiding duplication (there are several meterings, start, aproved, control,…).
- Inline Data Harmonization: Input fields are parsed using SQL string functions to derive consistent values.
- Spatial Readiness: Each inserted record is immediately assigned a spatial geometry, or with a placeholder coordinate, ensuring compatibility with spatial queries and WebGIS components.

This implementation provides a strong foundation for semi-automated data synchronization in ELMAP. The modular structure enables future extensions such as event-based orchestration (e.g., via PostgreSQL's LISTEN/NOTIFY), automated spatial enrichment (replacing the placeholder point with geocoded coordinates), and fine grained data validation prior to insertion.

By delegating intelligent data processing to the database layer, ELMAP achieves a decoupled architecture where data producers (e.g., field apps, CSV importers) and data integrators (e.g., reporting services, visualization modules) operate independently and coherently. The use of triggers and conditional functions minimizes human intervention while ensuring data consistency, timeliness, and spatial operability. This method exemplifies the fusion of traditional relational logic with spatial database capabilities (via PostGIS) in a modern utility information system, aligning with the service-oriented and event driven design principles that underpin the ELMAP platform.

As part of the advanced optimization of meter reading routes, electricity meters are treated as nodes within a routing graph based on OpenStreetMap (OSM) road data. Accurate geolocation of each meter is essential, as these positions directly influence the efficiency of the field routes. To determine and validate meter locations, a hybrid geospatial method is employed:

- Initial coordinates are derived from existing GIS datasets.
- Google Maps API is used to enhance positional accuracy where coordinates are missing or uncertain.
- GEOFABRIK OSM Buildings data are used as a validation layer as meter points are snapped to the nearest building within a 3 m radius. If a meter location does not fall within this buffer, it is flagged for manual review.
- OSM road network is utilized to construct the routing graph for meter readers.
- Additional validation and quality control is performed using official address registry data and high resolution orthophotos, ensuring spatial consistency between meters and infrastructure.

The routing itself is computed using pgRouting, leveraging algorithms such as Traveling Salesman Problem (TSP) to generate efficient traversal sequences. These computations are optimized through parallel processing, allowing the system to handle large-scale datasets in a performant manner. This algorithm not only improves the spatial accuracy of meter locations, but also enables intelligent recalculation of routes based on updated meter positions and evolving road infrastructure. As such, it supports dynamic workload balancing for field teams, ensuring that route planning takes into account the most current geospatial context and operational constraints.

5. Results and discussion

The implementation of the ELMAP system has demonstrated significant efficiency and scalability in handling high density 3D geospatial datasets, particularly those used for advanced energy infrastructure visualization. The evaluation was conducted on a dedicated Windows server equipped with 16 CPU cores, 16 GB RAM, and a 512 GB SSD. PostgreSQL version 17.3 was used as the core database engine, supporting spatial extensions via PostGIS.

The backend system architecture relies heavily on a streaming workflow where data are pulled directly from PostgreSQL and served via GeoServer as GeoJSON to the frontend. This pipeline supports real time rendering of both spatial and attribute information without intermediate file storage or additional caching layers.

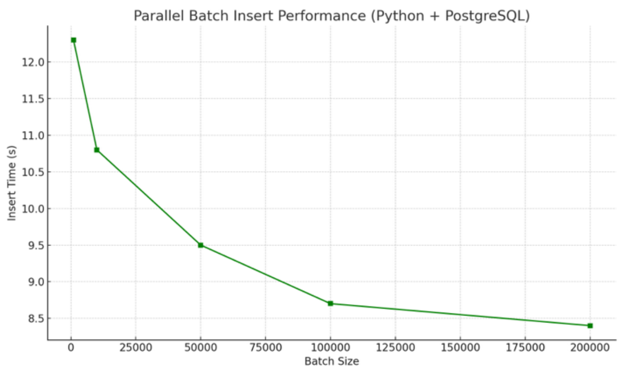

Figure 5. Parallel Batch Insert Performances.

Parallel processing was implemented using Python in combination with PostgreSQL to handle the insertion of more than 1,000,000 records (Automated Meter Measurement – AMM and Measurements by workers on the field). These insertions were chunked into batches and parallelized using Python multiprocessing capabilities. On Figure 5. is presented chart that outlines performance benefits for different batch sizes.

Batch inserts of up to 200,000 rows demonstrated a noticeable drop in insertion time, stabilizing around 8.4 seconds per batch. This result highlights the system's efficiency in high throughput data ingestion scenarios, which is especially relevant for time series data such as remote sensor readings. Another notable architectural element is the use of GeoServer, which plays a central role in data streaming and service orchestration. GeoServer delivers GeoJSON payloads directly from PostgreSQL spatial queries to the client, which are then dynamically styled and rendered in the browser using Mapbox GL JS. This approach minimizes latency, reduces processing overhead, and enables on-demand visualization of large datasets.

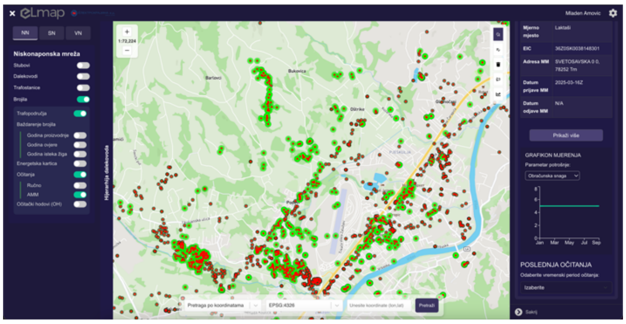

Figure 6. Meterings according to the type.

Furthermore, the system distinguishes between conventional and remote (AMM) measurements by segmenting them spatially and thematically (Figure 6.). Visual analytics tools allow filtering and overlaying of these datasets, enabling utility managers to compare legacy measurements with AMM derived data. The following image illustrates this distinction on the map interface. The rendering pipeline utilized Mapbox GL JS for client-side rendering, integrating with simple yet consistent .glb 3D models, each with identical geometric complexity (Figure 7.).

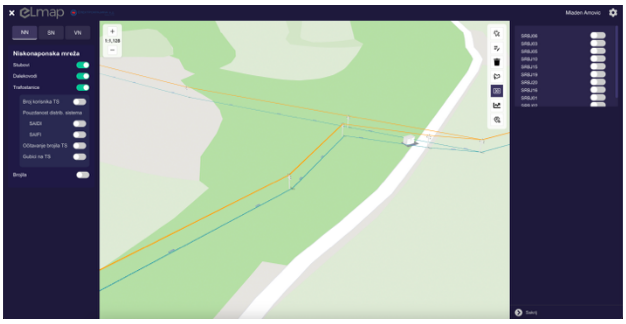

Figure 7. 3D Scene.

The 3D models were prepared with a 1:500 scale zoom dependent LOD strategy, allowing memory optimized rendering and better user experience without degrading detail at operational zoom levels. A key factor in performance improvement was the use of vGPU technology for WebGL acceleration.

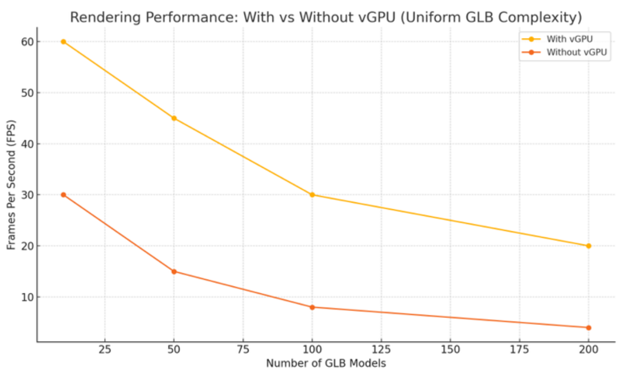

Figure 8. Rendering performances.

The system rendering capabilities were evaluated both with and without vGPU support. The Figure 8. shows the performance in terms of frames per second (FPS) across increasing number of 3D models. As seen in the results, enabling vGPU results in nearly double the FPS compared to setups without GPU support, especially as the number of rendered models grows. For example, rendering 100 GLB models yields 30 FPS with vGPU compared to only 8 FPS without it. This performance boost is critical for ensuring smooth user interaction in dense 3D urban scenes.

Feature	Technology Used	Impact
Rendering Engine	Mapbox GL JS + WebGL	High-performance real-time rendering
Model Format	Uniform .glb, 1:500 scale	Optimized memory and consistent visual output
GPU Acceleration	vGPU	2× performance improvement in FPS
Data Backend	PostgreSQL 17.3 + PostGIS	High-throughput spatial data storage
Streaming Middleware	GeoServer	Real-time GeoJSON delivery
Parallel Processing	Python multiprocessing + chunked inserts	Scalable ingestion for over 1 million rows
Visualization Layers	Segmentable by reading type (AMM vs conventional)	Enhanced analytical capability

Table 3. Benefits of the ELMAP system.

In Table 3. summary of key findings and benefits of the ELMAP system is presented, highlighting its role in enhancing the efficiency, accuracy, and reliability of managing geospatial data related to utility infrastructure. The system significantly improves data integration and visualization through standardized formats and real-time access, enabling better decision making and streamlined operations. Additionally, it supports interoperability between different platforms, contributing to increased transparency, improved maintenance planning, and overall optimization of infrastructure management processes.

6. Conclusion

This research presents an integrated and performance-optimized approach to the design and implementation of a WebGIS based system for managing electric utility infrastructure with strong emphasis on 3D data visualization, topological consistency, and high throughput data ingestion. The system leverages PostgreSQL 17.3 with PostGIS for geospatial data management, GeoServer for geospatial service streaming, and modern frontend technologies such as Mapbox GL for client side rendering. It is specifically tailored to handle millions of records from metering systems, also including remote smart metering systems (AMM), supported by a structured data model that guarantees topological coherence from segment to section and line, in 2D/3D context. The experimental results demonstrate that parallel data processing using Python with chunked batch inserts significantly improves ingestion speed and reduces system load. Moreover, the use of vGPU technology accelerates 3D rendering of .glb models uniform in complexity and scaled for optimal performance especially when dealing with massive point cloud and geometry datasets. System evaluation on a 16-CPU, 16GB RAM Windows server confirms that the architecture is capable of sustaining high performance streaming of GeoJSON outputs, even under intense visualization loads. Topological integrity is ensured via automated spatial validation and relational consistency checks between hierarchy levels. Additionally, the mapping between 2D and 3D data are performed in a scale aware and memory efficient manner, ensuring that large scale rendering remains usable and precise. The integration of GeoServer as a middleware service to expose and stream spatial content from PostgreSQL enables a modular and scalable architecture. This, combined with the optimization of render pipelines and hardware accelerated rendering via WebGL, establishes a robust platform suitable for future expansion, including real time analytics and predictive maintenance. The research confirms that with appropriate use of parallel processing, optimized data models, and GPU based rendering techniques, it is possible to build high performance, interactive, and scalable 3D enabled GIS management systems.

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