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Analysis of investment planning in electricity distribution systems with GIS

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Abstract

Efficient distribution of electrical energy is crucial in today's world. Geographic Information System (GIS) software plays a significant role in determining the traceability and measurability of electricity distribution. Distribution companies receive investment funds from affiliated organizations to make investments in their service areas. This study analyzes the effective utilization of these investment funds and the selection of appropriate areas for investment through geometric and semantic data using GIS applications. In this study, an investment plan was developed for the Seyrantepe neighborhood, a densely populated area in the Karaköprü district of Sanliurfa province, where energy waste occurs due to unauthorized energy consumption. Electrical grid and spatial analysis were conducted using the GIS system. Three main criteria were considered in determining the relevant area: unauthorized energy density, uninterrupted energy supply, and new subscription processes. The entire process was carried out using GIS software, which involved defining an identity (project code) for the planned area and conducting analysis and obtaining results through SQL queries. The integration of electrical measurement circuits of subscribers and provision of quality and uninterrupted electricity to new settlement areas were achieved through GIS-enabled visualization using the software. Using this software, an investment plan was identified that could reduce the region's unauthorized consumption and System Average Interruption Frequency Index by approximately three times.

1. Introduction

In today's world, the demand for electricity is increasing every day due to factors such as advancing technological investments, population growth, and unconscious consumption. The correct and efficient distribution of this energy is of vital importance for the future world, alongside the policies implemented to increase electricity production in line with these demands.

The Energy Market Regulatory Authority (EPDK) was established to ensure the efficient use of electrical energy, the seamless establishment of the supply network, and the determination and management of rules and procedures that both individual and commercial users must adhere to (EPDK, 2017). In a situation where energy has gained such importance, especially due to the absence of storage options, Geographic Information System (GIS) applications play a significant role for all distribution companies. The EPDK allocates budgets to distribution companies in order to promote the healthy use and proper transfer of energy, allowing them to perform various analyses in GIS applications using specific SQL queries to analyze and visualize the results of these budgets in the field.

To effectively utilize this comprehensive yet non-storable energy source, the key is to transmit high-quality electrical energy with minimal losses and in the shortest route from its point of generation to the end user. Significant technological advancements have been made in the field of transmission and distribution in the past to address this challenge, and this progress continues today (Rao, 2008). When considering all components of an electrical network that caters to the entire energy demand of a region, from transmission facilities to consumer meters, as spatially referenced data, it becomes inevitable to utilize GIS for data management, querying, and analysis (Ünverdi, 2021). Additionally, continuous monitoring and examination of electrical grids in a geographic sense are necessary to provide the best service to users. Performing these tasks on paper maps or using a system that cannot ensure

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standardization appears impractical. Updating, duplicating, sharing, analyzing, and querying operations on paper maps are time-consuming and costly, and the data integrity cannot be ensured as verbal information about objects is stored in different formats and locations (Emiroğlu, 2007).

The rate of electricity theft constitutes the majority of the overall loss and leakage rate in Türkiye. As mentioned earlier, the annual average loss and leakage rate in Türkiye is around 15%. Since technical and administrative losses are within the minimum standard, they do not pose a significant problem. On the other hand, the increasing adoption of principles such as material quality, workmanship, and the use of modern and state-of-the-art devices will pave the way for further reduction of technical and administrative losses. In our country, technical and administrative losses range from 3% to 7%, while non-technical losses range from 10% to 15%. In short, there is a leakage rate of 10% in total production. According to EPDK data, the highest rate of electricity theft occurs in the eastern regions. The Dicle, Aras, and Vangölü regions sometimes experience theft rates of up to 60% (Aksu, 2019).

For accurate analysis of investments in Sanliurfa province, a leading region in loss and leakage rate (LLR) rankings in Türkiye, it is crucial to utilize GIS applications in a highly technological and efficient manner. Spatial information, including attribute data for all inventories within the distribution area, is integrated and kept up to date in the GIS application. The current state of the field is assessed by incorporating satellite imagery obtained from various providers as the basemap, and the network infrastructure is determined based on existing structures.

Critical applications such as efficient energy distribution, real-time access to digital data, visual analysis, and investment planning to prevent energy waste have been implemented through GIS applications in the study area.

2. Study Area

The Seyrantepe neighborhood of Karaköprü district in Sanliurfa has witnessed a rapid acceleration in urbanization in recent years (Figure 1). Despite the increased risk of earthquakes due to the rocky soil structure and the general climate, there has been a rapid population growth (Gökler, 2020).

As agricultural areas rapidly diminish (Hatipoğlu, 2018), urbanization in this region naturally leads to an increased demand for electricity and the need for investment. In this context, one of the most important criteria for selecting the study area is the integration of LLR with the electrical measurement devices available in the GIS environment. Therefore, streets numbered 8030, 8071, 8069, and 8040, which show higher LLR measurements compared to other areas, have been selected as the study area for Seyrantepe neighborhood (Figure 2). In the GIS environment, a total of 385 subscriptions have been identified for this area. This value indicates that the number of subscribers in this region is suitable for electricity investment.

Figure 1. Study Area

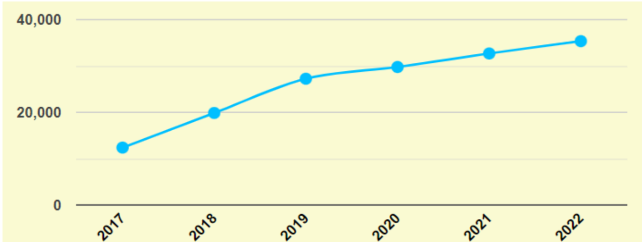

Figure 2. Annual population change of the neighborhood (TURKSTAT, 2023)

3. Material and Method

MapInfo and Edabis desktop-field-web applications were used as GIS software. The selection of the relevant area was based on factors such as loss and leakage due to unauthorized energy use, quality and uninterrupted power supply, new subscription processes, and new settlement areas. Google and Yandex satellite images were used as a base map in the GIS software for ground control of buildings and electrical networks. Geometric and semantic information, including electricity subscribers, floor count, and address (city-district-neighborhood-street), was obtained for all buildings in the study area, and a base map was provided for the use of the electrical network.

The existing condition prior to the investment in the relevant area has been recorded as the initial condition project in the Edabis application (Figure 3). Attribute information for the materials to be removed, including length, year, current condition, type, and usage method, has been determined through the query screen in the software. The amount of loss and leakage in the area has been determined through the integration of the transformer leakage analysis in the GIS software, and the undergrounding of the electrical network has been planned in the GIS environment to prevent external interventions. The installation of Field Distribution Boxes (FDB) and underground cables for each inventory to be removed from the field has also been planned in the GIS environment.

The selection of investment areas based on specific criteria and the planning of investments in these areas in the GIS environment are necessary before starting field work. This allows for a realistic assessment of the return on investment and accuracy prior to fieldwork. The criteria used in the selection of investment locations are described in the following subheadings.

3.1. Detection of unauthorized energy usage

All electrical inventory used in the field, through the electronic chips and sensors present in the inventory, performs real-time measurements and sends this information to the Mapinfo-based Edabis GIS software using ID numbers. Based on these data, the discrepancies between the supplied energy and the billed energy can be spatially analyzed and obtained through the KKO (Loss and Leakage) system in the system. In this context, the KKO system in the study area has been measured as 47.9%. Since this value is high compared to the surrounding areas, this region has been selected for investment (Figure 4).

Figure 3. Initial condition of the study area

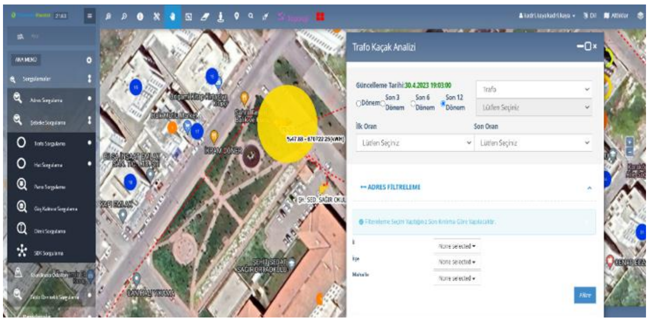

Figure 4. Integration of GIS Transformer Leakage Analysis

3.2. High-Quality and Continuous Energy Supply

The main duty of all distribution companies is to provide high-quality and uninterrupted energy. Investments are planned considering the service life of electrical inventory and the increasing use of electronic devices in today's world. Attribute information of the inventory in the field is kept up to date in the GIS software. This enables the reporting of information such as the production year and facility of the inventory through the GIS, determining the necessity of network renewal. Additionally, the consumption levels of the subscribers in the region have been analyzed using the registered measurement devices in the system, and an increasing consumption trend has been identified in the area. Taking this information into account, the investment to be implemented has been designed to accommodate the expected increase in inventory and meet the projected consumption levels.

3.3. Tracking of New Subscription Processes

When determining the investment area, the new subscriber numbers in the regions can be spatially identified through the integration of the electricity subscriber system with GIS. This situation necessitates network improvements and investment in areas where the new subscriber count is relatively high. In this context, the analysis of spatial and electrical growth can be conducted using GIS to determine the extent of investment required in these areas. In the analysis conducted within the study area, it has been determined that this region also requires investment in terms of new subscriptions.

4. Results

All GIS analyses are carried out using a GIS software called Edabis, which is specifically designed for the distribution company based on MapInfo. The initial observation status for the area to be invested in has been determined both visually and numerically, and the information regarding the list of areas for investment has been reported to the EPDK. Once the approval and budget for the investments are obtained, the relevant information for the area in question is identified in the GIS environment.

The planning phase was conducted by comparing the current situation in the field with the GIS. The inventory to be removed from the relevant area was identified numerically through SQL queries in the Edabis system, and it was recycled and recorded for use in other areas. With the assigned codes for each investment area, simple queries can be made through the GIS to continuously monitor the respective area.

The three main criteria for the investment areas, which are unauthorized consumption, quality and uninterrupted energy supply, and new subscription processes, have been identified using geometric and semantic data, and the necessary analyses have been conducted through the Edabis and MapInfo GIS software. These data have been obtained through the integration of the GIS software with electrical measuring devices, base satellite images, citizen applications, loss-leakage integration, and the semantic data of the network.

The inventory related to the planned investment has been compared in terms of pre-investment and post-investment conditions based on the current situation and analysis in the study area (Table 1).

Table 1. Pre and Post Investment Status of the Study Area

	Transformer	Pole/ FDB	LV Line (m)	Lighting pole
Pre-investment	2	72	3786	100
Post-investment	1	61	4200	120

If this planned investment is implemented, according to the analysis obtained through the GIS software, one of the most important issues for distribution companies, the System Average Interruption Frequency Index, will be reduced by three times. Furthermore, the analysis results indicate that power outages will be minimized, and no inconvenience will be experienced in new subscription applications.

By assigning a specific code to this project in the GIS software, it has been recorded and can be visualized through SQL queries for potential fieldwork in the study area. This enables the digital monitoring of every planned scenario for electricity distribution without the need for additional fieldwork (Figure 5). Moreover, each electrical inventory item removed in the field can be recycled. The reporting of these removed inventories can also be carried out through the demolition query screen in the GIS software. These inventories can be tracked through the integration of Google Street View within the GIS software (Figure 6).

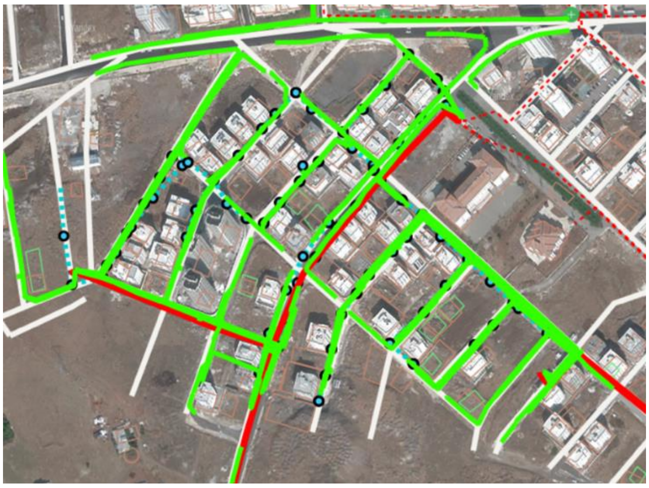

Figure 5. The Final Status of the Study Area

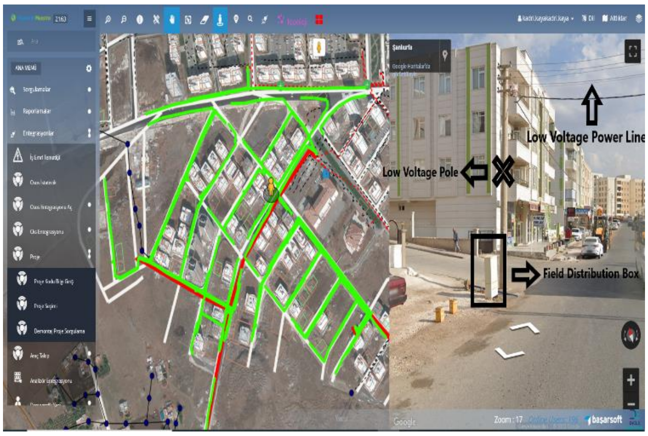

Figure 6. Google Street View of the Study Area

5. Conclusion

The main objective of this study is to analyze both pre and post-investment scenarios of all investments made by distribution companies using GIS and solve potential scenarios. The first objective of the study is to determine the suitability of making investments in the relevant area. The second objective is to observe improvements after the investment. These improvements can be measured through factors such as customer satisfaction when quality and uninterrupted energy are provided, reduction in workload, time savings, and cost savings. Additionally, the recycling of removed inventories is also an important factor. It has been demonstrated that all of these factors can be evaluated through GIS investment analysis.

With the increasing energy demand in today's world, it is observed that especially the analysis of loss and leakage amounts can be done accurately through GIS. In the study area, the loss and leakage rate, which has been determined as 47.88%, and System Average Interruption Frequency Index, projected to be reduced by three times through accurate analysis and investments.

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