



Analysis of Magnetic and Electric Fields in the Vicinity of the High-Voltage Transmission Line

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Abstract

This study presents an overview of the High Voltage Overhead Line (SUTT) located within the residential areas of Buduran District, Sidoarjo, highlighting its spatial characteristics and potential implications for the surrounding community environment. Previous studies on magnetic and electric fields around high-voltage transmission lines are mostly conducted in generalized or large-scale urban and industrial settings. However, localized assessments in specific residential or semi-urban areas such as Buduran remain scarce, leaving uncertainty about the actual exposure levels experienced by surrounding communities. This research is a quantitative descriptive analysis using IEEE Standards for EMI in transmission lines, sampling was carried out in 4 different settlements passed by SUTT were Pager Wojo Village, Sidokepung Village, Sidokerto Village and Buduran Village. The findings show that the magnetic field and electric field values for the four villages in Buduran District were classified as safe, namely 0.2 to 1.12 V/m for the electric field and 1 to 130 micro-Tesla for the magnetic field around the 4 villages. The magnetic field and electric field are generated by SUTT, which is 10 meters from the nearest house. So, the Buduran District area is suitable for use as a settlement even though it is passed by SUTT.

Keywords: Magnetic Field; Electric Field; High Voltage Overhead Line

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INTRODUCTION

Every year, residential areas become increasingly dense, especially in the Buduran district, Sidoarjo. However, safety and health factors for land users are not given enough attention. The position of Buduran District, Sidoarjo is considered quite strategic, namely in the south of Surabaya. Apart from the strategic geographic side, from an economic perspective, Buduran, Sidoarjo is also developing rapidly. Many say that Delta City is like a magnet that attracts housing seekers and investors. The demand for housing in Buduran, Sidoarjo is getting higher as time goes by (Ridhoi, R., & Wahid, A. 2017). In 2016 there was an explosion in the number of settlements which reached 7% based on data from the Buduran Regency Government, Sidoarjo. From data obtained from the Buduran district government, Sidoarjo, the number of residences has now reached 597 settlements spread across 15 sub-districts (Resantie, L., & Santoso, E. B. 2020). The development of residential development which increasingly takes up a lot of land will intersect with the development of large-scale electricity sources, namely SUTT (High Voltage Air Lines). It cannot be denied that human survival cannot be separated from dependence on electrical energy. The availability of electrical energy to users or consumers is usually quite far away, so an electric power transmission/line is needed. Previous electromagnetic field (EMF) measurement and health studies generally report mixed and often inconclusive results: many technical surveys document that EMF levels near

high-voltage lines can exceed typical residential background but frequently remain below international exposure limits, while epidemiological research shows inconsistent associations between long-term low-level exposure and adverse health outcomes. In the Buduran context, what is missing are locally specific, methodologically rigorous data and analyses: comprehensive, long-term EMF monitoring (including spot, continuous, and personal exposure measurements across seasons), high-resolution spatial mapping tied to residential density, and epidemiological or health-surveillance studies that link exposure estimates to measurable health outcomes while controlling for socioeconomic and environmental confounders. Additionally, assessments of community risk perception and the effectiveness of any mitigation measures are absent and needed to inform local policy. Therefore, to reduce losses and efficiency of transmission lines, the voltage is increased to extra high, namely 150 kV (in Indonesia). This transmission channel is usually called SUTT. The existence of SUTT will cause radiation, namely magnetic field, and electric field radiation. Electric fields and magnetic fields belong to the group of non-ionizing radiation (Kementerian Kesehatan RI. 2023; World Health Organization. 2016). The assumption that SUTT is harmful to health tends to be widely questioned as to its accuracy when compared to its benefits. In several issues, the cases had long tails until rumors began to emerge that the people who lived under the SUTT tower felt disadvantaged in terms of human health because they felt that the various illnesses they experienced were caused by the influence of the electric and magnetic fields generated by SUTT (Anand, N., & Moses, M. B. 2025; Balaji, A. 2015; Dervish, M. H. 2017).

Given the importance of electrical energy for daily life and the increasing proximity of residential areas to high-voltage transmission lines, it is crucial to thoroughly investigate and address these health concerns. Conducting rigorous scientific research and maintaining transparent communication with the public are essential steps in either validating or dispelling the perceived health risks. This balanced approach is necessary to ensure both the continued reliable supply of electrical energy and the health and well-being of the communities residing near these critical infrastructures (Banerjee, A., et., al. 2020; Alam, M., et. Al., 2022; Branco, C., et al. 2023; Rogger, D., & Somani, R. 2023). The distribution of community settlements in Buduran District is evenly distributed in all directions. Starting from river coasts, national roads, railway tracks and close to national objects, namely Extra High Voltage Air Lines (SUTET) and High Voltage Air Lines (SUTT). Based on the Electricity Law, PLN as a BUMN in providing electric power has the right to pass over land/or buildings belonging to the Community (Rights of Ways), while still complying with the safe limits of electromagnetic induction in accordance with the Regulation of the Minister of Energy and Mineral Resources regarding Free Space and Minimum Free Distance in SUTT, SUTET (Ren, S., Bao, R., & Gao, Z. 2025). In its development, the regulations underwent updates, namely PERMEN PE.01.P/47/m.PE/1992, which underwent several changes until the latest update was PERMEN ESDM No. 18 of 2015 in conjunction with No. 2 of 2019. In the new regulations, the provisions for free space and minimum free distances for SUTT, SUTET and SUTTAS are re-regulated in distributing electric power (Kementerian Kesehatan RI. 2023). Simulation ways had been test using Finite element analysis and ANSYS electronics to know distance effect on High voltage through the hight of human and towers. The result is a safety distance above 60 m. Under 60 m, the Electric field still strenght and have an impact for human especially in range 20 – 45 m because this point is peak of electric field (Republik Indonesia. 2009).

Previous research from Haryono and Sudarti (Haryono, & Sudarti. 2013) regarding factor analysis of the impact of SUTET on public health in Tulangan Buduran District, Sidoarjo stated that in this study the population aged 15 - 49 years with a total sample size of 220 people consisted of 100 people in the exposed group, namely the group of people who reside at 0 - 50 m lateral to the SUTET-500 kV transmission network. Meanwhile, the control group consisted of 80 people who lived at more than 200 m lateral to the SUTET-500 kV transmission network. The average ELF electric and magnetic field intensities inside houses and in the yards of

residents in the exposed area are (12.97 V/m, 0.382 μ T) and (89.10 V/m, 0.367 μ T). Meanwhile, the average ELF electric and magnetic field intensity in the control region is (4.23 V/m, 0.044 μ T). This shows that the presence of SUTET-500 kV significantly increases the intensity of exposure to ELF electric and magnetic fields in the environment but is still below the exposure threshold value according to WHO. A similar research by M. Y. Asrami in 2022 (Yazdani-Asrami, M., et al. 2022) on effect of E/H field on UAV operation. Then research from Sari in 2016 (Sari, & Tani, M. 2016), Electric power plants to meet the electricity needs of an area (load center), are usually located far from the load center. The distance between the electric power source and the load center usually reaches tens or even hundreds of kilometers, which is distributed via a network or transmission line. However, the 150 KV high voltage transmission network can create an electric field which will affect the surrounding loads, including the residential environment and humans along the network. E. Lunca in 2018 analyzed for 400 kV transmission line used simulations to validate finding and offer an analytical of the EMF distribution for safety regulations and evaluation for High Voltage in district. Also R. Dianovsky in 2023 (Lunca, E., et al. 2018) and A. Zamanian in 2005 (Dianovský, R., et al. 2023) founding the impact of Electro Magnetic Field (EMFs) is very dangers because the strength of magnetic, electric and radiofrequency field and causing cancer. A.H. Khawaja in 2017 (Zamanian, A., & Hardiman, C. J. H. F. E. 2005) proposed noncontact measurement for EMF. An outline of techniques for examining electricity transmission cables using non-contact sensing. The study concentrated on employing real-time remote sensing for fault detection and smart grid deployment in order to increase the efficiency and security of grid operations. Also K.K. Kachari in 2025 (Kachari, K. K., 2025) developed a Wire Electrical Discharge Machining (WEDM) for discharge monitoring.

By looking at several analyzes of the impact of SUTT on the health of the surrounding community, the purpose of this study is to assess the levels of electric and magnetic field exposure generated by the high-voltage transmission line and compare these measurements with established national and international safety guidelines to determine whether the exposure experienced by the surrounding community remains within acceptable limits. In summary, the use of a Prototype Induction Meter around SUTT in Sidoarjo is a critical step in understanding and managing the impact of magnetic field radiation.

METHOD

Types and Research Approaches

This research uses quantitative descriptive analysis. This research aims to determine the livability conditions using indicators of magnetic field and electric field radiation values for settlements around SUTT.

IEEE Standards for EMI in transmission lines to measure WHO standards on Electric field

IEEE Recommended Practice for Measuring Method of Electromagnetic Environment for the Corridor of High-Voltage Overhead Power Transmission Lines in Parallel Mixed with Alternating Current and Direct Current. In cases where power TLs are constructed in parallel or on shared towers, this recommended procedure creates consistent techniques for monitoring the DC electric field and power frequency electric field. The mutual interaction of parallel power TL is examined using theoretical computation and on-site areas as the foundation for the specifications and calibration methods for electric field meters. The IEEE guidelines provide internationally recognized technical specifications for evaluating electromagnetic fields, interference limits, measurement procedures, and safety considerations around high-voltage power systems. By applying these standards, the study ensures that the assessment of electric and magnetic field exposure follows validated methodologies, maintains measurement accuracy, and aligns with global best practices. Using the IEEE framework also enables the results to be compared transparently with established threshold values, thereby supporting a

reliable evaluation of potential EMI impacts on the surrounding residential environment. There are established measurement ranges and point layouts, data collecting and processing protocols, and methods for assessing the outcomes for parallel power transmission lines with different voltage levels. This suggested method can be used to measure the electromagnetic environment of parallel TL with a separation of no more than 100 m, dc TL with a voltage of at least 400 kV, and ac TL with a voltage of at least 100 kV.

This study employs the IEEE standards (IEEE, 2022) as the primary reference framework for evaluating electric and magnetic field exposure around the transmission line or measurement purposes :for magnetic field (power frequency, general public): about 9,040 milligauss (mG) (≈ 9.04 gauss) for whole-body exposure under certain conditions; for electric field (power frequency, general public): some sources quote up to 5.0 kV/m (on the right-of-way of high-voltage overhead lines) as a guideline reference for transmission-line exposure.

Research variables

Sampling was carried out in Buduran District it captures local settlement characteristics, population density, land use patterns, and proximity of residential zones to the SUTT and SUTET transmission corridors and obtained 4 villages, namely Pager Wojo Village (1 sample point), Sidokepung Village (1 sample point), Sidokerto Village (1 sample point) and Buduran Village (1 sample point). This variable ensures accurate spatial mapping of electric and magnetic field levels and supports geospatial analysis along the transmission line route. This variable accounts for environmental conditions which may influence electric and magnetic field intensity. The initial stage carried out for this research was calibrating the magnetic field radiation measurement equipment and continued with finding the radiation measurement location. The tool used is also equipped with an HCSR sensor to measure the closest distance to SUTT. The stages for obtaining information on the radiation value of each settlement can be seen in the flow chart in Figure 1.

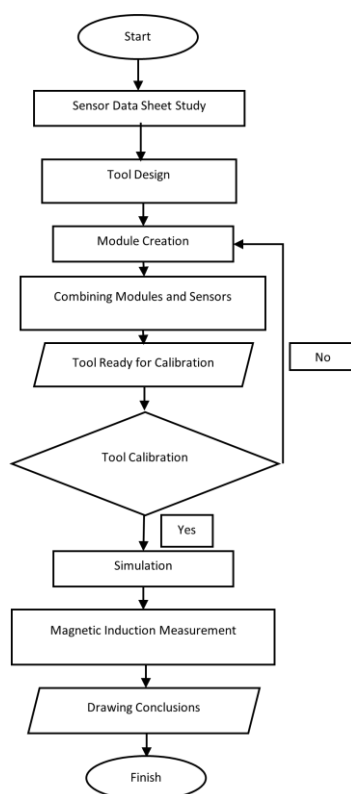


Figure 1. Research flow

This flow chart outlines the systematic process employed to gather and analyze radiation data within various residential areas. The initial step involves setting up the necessary

equipment and sensors to measure the radiation levels accurately. We thoroughly examined a number of pertinent and extremely precise sensors for application in the creation of magnetic field measurement instruments. Before starting the manufacturing process, a literature review was carried out by looking for relevant sensor data sheets. Making a design that could accommodate field measurements was the next step. The measurement tool's design was kept as simple as possible without sacrificing any crucial information that needs to be shown. After that, we designed a module and paired it with sensors that worked with the magnetic measurement instrument. When developing a measuring tool, the calibration stage is essential since it enables us to ascertain the tool's offset and restrictions. A measuring device with a high degree of accuracy can be produced by proper calibration. Field measurements and inferences from the measured area constitute the last phase. In testing the magnetic field and electric field, two sensors are utilized, as depicted in the design schematic shown in Figure 2.

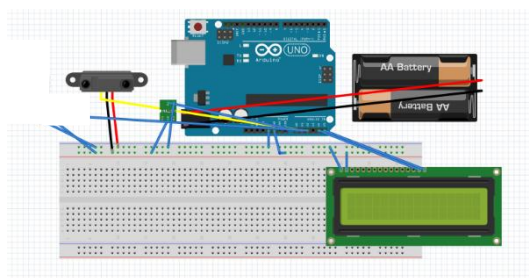


Figure 2. Schematic of the tool

The Hall Effect sensor is specifically used to measure the strength of the magnetic field. This sensor operates by detecting the voltage generated when a magnetic field is applied perpendicular to the flow of current within the sensor's material. The Hall element transducer is a thin strip of metal that receives a fixed DC bias current delivered along one axis in a Hall sensor. The difference in electric potential (voltage) across the electrodes' axis is measured by sensing electrodes on either side of the Hall element along a different axis. When there is a magnetic field perpendicular to the current's flow, the Lorentz force deflects the charge carriers. The Hall voltage, which is proportional to the axial component of the magnetic field perpendicular to the axis of the sensing electrodes and the current, is measured by the sensing electrodes. The resulting voltage, known as the Hall voltage, is directly proportional to the strength of the magnetic field, providing precise measurements. The magnetic field's strength is quantified in units of Gauss or Tesla, allowing for standardized and comparable data collection.

Alongside the Hall Effect sensor, another sensor is employed to measure the electric field. This sensor captures the intensity of the electric field present in the environment, contributing to a comprehensive understanding of the radiation levels. The collected data from both sensors is then processed and analyzed to determine the overall radiation impact on each settlement. The sensors used in the magnetic field measuring instrument are the hall effect sensor and distance sensor added as an additional indicator.

The use of a distance sensor is essential in SUTT/SUTET measurements because the intensity of electric and magnetic fields decreases significantly with increasing distance from the conductor. Accurate distance data ensure that each measurement point is precisely documented, allowing reliable assessment of field attenuation patterns and compliance with exposure guidelines.

RESULTS AND DISCUSSION

Tool Calibration

Making a magnetic field measurement tool first goes through the initial stage, namely tool calibration. Based on Figure 2, the linearity of changes in magnetic field readings

regarding the ADC value and the PASCO comparison tool is obtained. The linearity obtained by the measuring instrument was 94.08% compared to the PASCO instrument which was 95.39% for changes in the applied magnetic field. This indicates that the measuring instrument has a good response to changes. After obtaining the change in the ADCD value to the Gauss value. Shows the relationship between ADC and Gauss where 1-10 ADC is equal to 1 Gauss. The relationship between changes in PASCO readings can be seen through the Equation 1, and measuring instruments readings can be seen through Equation 2.

$$Y = -3,6402x + 573,31 \quad (1)$$

$$Y = -1,3277x + 10,742 \quad (2)$$

By entering the value $x = 1$ into each linear equation, the y value is obtained as an ADC reading against Gauss of 570 ADC for the 1 Gauss condition as shown in figure 3.

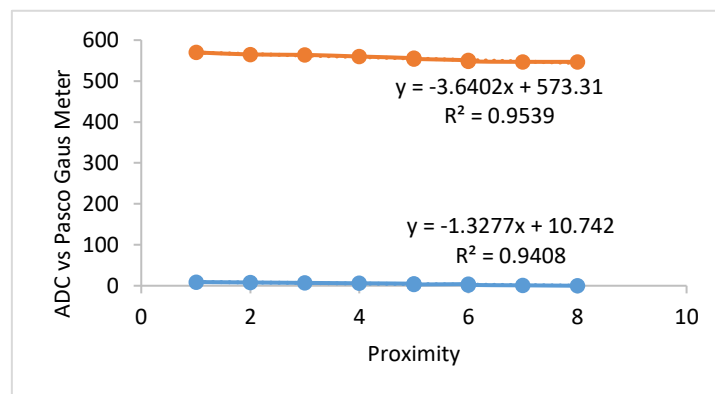


Figure 3. Calibration of the Hall Effect Sensor ADC against the PASCO comparator to determine sensor linearity and ADC to Gaussian conversion

Measurement of the Electric Field Around SUTT

Electric field and magnetic field measurement data have been collected from four villages located in the Buduran District, Sidoarjo Regency. These measurements were conducted in areas surrounding a High Voltage Transmission Line (SUTT) that traverses residential communities, as illustrated in Figures 4 and 5. The purpose of this monitoring activity was to evaluate potential exposure levels among the local population and assess their compliance with international safety standards. The recorded electric field strengths in the four surveyed villages were as follows: 0.7 V/m in Pagerwojo Village (-7.439463, 112.705162), 1.13 V/m in Sidokepong Village (-7.416918, 112.707001), 0.5 V/m in Sidokerto Village (-7.424131, 112.706415), and 0.2 V/m in Buduran Village (-7.413392, 112.707418).

In terms of magnetic field strength, the measurements yielded values of 4 microtesla (μT) in Pagerwojo, 130 μT in Sidokepong, 104 μT in Sidokerto, and 1 μT in Buduran. According to the World Health Organization (WHO) guidelines (Yazdani-Asrmi, M., et al. 2022; Nainggolan, D. V., 2016), the recommended safety threshold for electric field exposure is 5 kilovolts per meter (kV/m), while the limit for magnetic field exposure is set at 0.1 millitesla (mT), equivalent to 100 μT . When comparing the recorded data from the Buduran District with these international benchmarks, it is evident that the electric field levels in all four villages fall significantly below the 5 kV/m threshold, indicating no immediate risk of harmful exposure to residents in terms of electric field intensity.

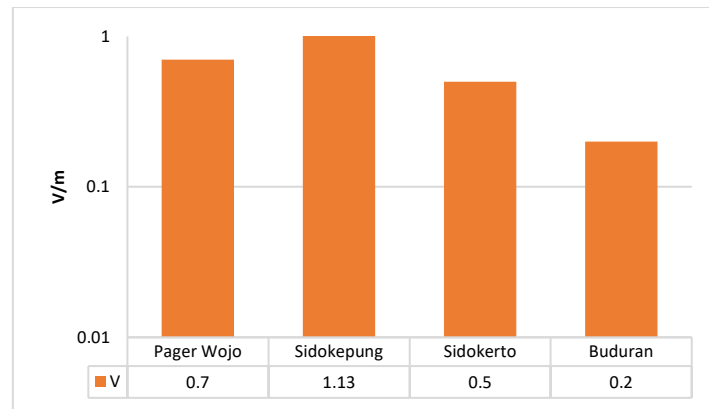


Figure 4. SUTT Electric Field Value for Buduran Area, Sidoarjo

However, with regard to magnetic fields, the data reveals a more nuanced picture. While Pagerwojo and Buduran Villages report magnetic field values of 4 μT and 1 μT respectively—both well within safe exposure limits—Sidokepeng and Sidokerto Villages recorded magnetic field strengths of 130 μT and 104 μT , slightly exceeding the WHO's recommended maximum threshold of 100 μT . This suggests that in certain locations, particularly in Sidokepeng and Sidokerto, there may be a need for closer monitoring and possibly further investigation to determine long-term exposure risks and appropriate mitigation measures. In summary, while the electric field strengths in all surveyed areas are comfortably within safe limits, the magnetic field strengths in two of the four villages approach or surpass the WHO guideline, indicating potential health considerations for residents living in close proximity to high voltage infrastructure.

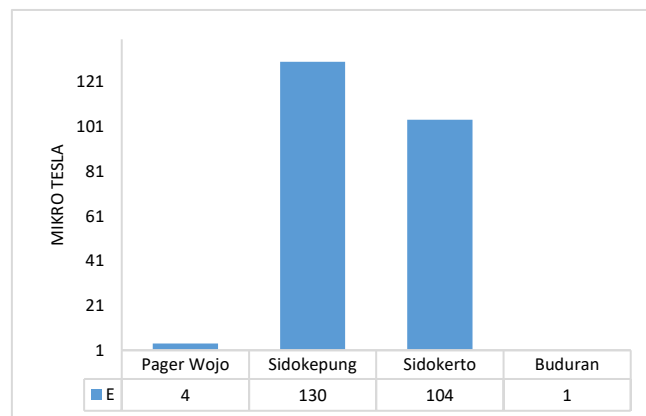


Figure 5. Magnetic Field Values of SUTT Buduran Region, Sidoarjo

Calculation of the Electric Field Around SUTT

The next stage is a comparison between measurements and calculations to determine the value of the magnetic field and electric field in villages throughout Buduran District. Using the electric field strength equation under the 150 KV transmission line, consisting of strength E .

$$E_{xa} = \frac{(Q_{ra} + jQ_{ia})(X_n - X_a)}{2\pi\epsilon[(X_a - X_n)^2 + (Y_a - Y_n)^2]} - \frac{(Q_{ra} - jQ_{ia})(X_n - X_a)}{2\pi\epsilon[(X_a - X_n)^2 + (Y_a - Y_n)^2]} \quad (3)$$

Description:

Q_{ra} = Real charge point a

Q_{ia} = Imaginary charge at point a

X_a = Human distance

X_n = Distance SUTT point a

Y_n = Human height

Yes = SUTT height point a

P = Parameter ($1/2\pi\epsilon$)

Based on the calculations conducted using formula (3), the electric field strength for the Pagerwojo area was determined, taking into account the specific environmental and spatial characteristics outlined in Table 1. By applying the relevant parameters obtained from previous references and measurement data, the computed value for the electric field at the lowest point in the area was found to be $E = 0.6289 \text{ V/m}$. This value reflects the electric field intensity generated around the high-voltage transmission infrastructure present in the Pagerwojo region. When compared with the safety threshold established by the World Health Organization (WHO), which stipulates a maximum safe exposure limit of 5 kilovolts per meter (kV/m), it is evident that the computed electric field strength is significantly below the harmful exposure level. Specifically, the electric field in Pagerwojo is approximately an order of magnitude lower than the WHO threshold, indicating that the level of exposure in this area is within acceptable and safe limits for the general population. These findings further reinforce the observational data obtained during field measurements and suggest that, under current operating conditions and environmental configurations, the electromagnetic exposure due to electric fields in Pagerwojo does not pose a significant health risk to residents.

Table 1 Characteristics of the Buduran SUTT Location

Symbol	Value
Xn	10 m
Ya	25 m
Yn	1,8 m
Xa	4 m
P	1,46011E+11
Qra	7,00 E-10
Qia	2,30E-10

Mapping the Buduran Area that SUTT has missed

Magnetic field and electric field measurements in the Buduran District area were carried out in villages passed by SUTT. The location of Buduran District is in the middle of Sidoarjo Regency. The electricity flow that passes through Buduran District will be connected to the Waru electricity substation all the way to Tulangan. Figure 6 shows the location of Buduran District. The location of Buduran District, which is in the middle of the district, is where the vital state object, namely SUTT, passes. Figure 7 shows the flow of the SUTT route which passes through Buduran District. The red line represents the traversed area. Buduran sub-district is in the center of the district, but the areas that SUTT passes through are only on the outskirts of the sub-district. From the measurements and calculations that have been carried out. We can map that the 4 villages passed by SUTT are safe for the health of the surrounding community because they are still less than the WHO threshold.



Figure 6. Data Collection Location

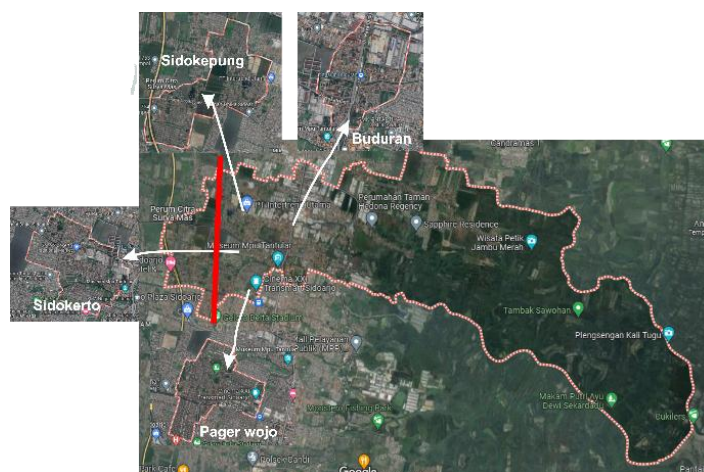


Figure 7. View of Buduran District as passed by SUTT

The mapping of the SUTT route is clarified in Figure 8. Where the SUTT route passes through Sidokepung Village, which is at the northern tip of Buduran District, then passes through Buduran Village and is connected to Sidokerto Village. The last village to be passed in the south is Pagerwojo Village which is on the direct border with Sidoarjo District.



Figure 8. Zoom of Mapping

CONCLUSION

In research regarding the analysis of community health around SUTT in the Buduran District area, it can be concluded that there are 4 villages in Buduran District which are the SUTT crossing route, namely Pagerwojo Village, Sidokerto Village, Buduran Village and Sidokepung Village. The magnetic field and electric field values were obtained for each village that SUTT passed, namely Pagerwojo Village, for an electric field of 0.7 V/m and a magnetic field of 4 micro-Tesla. Sidokerto Village for an electric field of 1.13 V/m and a magnetic field of 130 micro-Tesla. Buduran Village for an electric field of 0.5 V/m and a magnetic field of 104 micro-Tesla and Sidokepung Village for an electric field of 0.2 V/m and a magnetic field of 1 micro-Tesla. These four villages exhibit voltage levels that exceed the standard threshold, which may pose potential adverse impacts, including risks to human health. Furthermore, this issue should be a significant consideration for local authorities in order to mitigate the adverse effects of high electrical voltage in residential areas.

RECOMMENDATION

The development of research on the impact of high-voltage electricity areas on public health is urgently needed, especially in densely populated communities. The presence of extra-high voltage power lines or substations near residential areas exposes people to long-term electromagnetic fields (EMF), which have been associated in various studies with potential health issues such as sleep disturbances, stress, headaches, and even risks of chronic diseases. At the same time, the growing demand for energy requires the expansion of large-scale electrical infrastructure, often intersecting with urban settlements. This situation creates a tension between ensuring energy supply and safeguarding community health. Therefore, comprehensive and evidence-based research is essential to clarify the real level of risk, provide scientific guidance for safety standards, and recommend appropriate policies. Such research will help ensure that energy development can proceed without compromising the well-being of densely populated communities.

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Author Contributions Statement

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Dzulkiflih	✓	✓		✓				✓		✓	✓	✓	✓	
Imam Syaroni		✓	✓	✓				✓	✓					
W B Syahputro				✓	✓	✓	✓		✓					

Conflict of Interest Statement

Authors state no conflict of interest

REFERENCES

- Alam, M., Dappe, M. H., Melecky, M., & Goldblatt, R. (2022). Wider economic benefits of transport corridors: Evidence from international development organizations. *Journal of Development Economics*, 158, 102900. <https://doi.org/10.1016/j.jdeveco.2022.102900>
- Anand, N., & Moses, M. B. (2025). Electromagnetic radiation detection and monitoring in high-voltage transmission lines using machine learning techniques. *Measurement*, 253(C), 117645.
- Balaji, A. (2015, Juni). Effect of high voltage transmission lines on human health, plant life, and animal activity. *International Research Journal of Engineering and Technology (IRJET)*, 2(3).
- Banerjee, A., Duflo, E., & Qian, N. (2020). On the road: Access to transportation infrastructure and economic growth in China. *Journal of Development Economics*, 145, 102442. <https://doi.org/10.1016/j.jdeveco.2020.102442>
- Branco, C., Dohse, D. C., Santos, J. P., & Tavares, J. (2023). Nobody's gonna slow me down? The effects of a transportation cost shock on firm performance and behavior. *Journal of Urban Economics*, 136, 103569. <https://doi.org/10.1016/j.jue.2023.103569>
- Dervish, M. H. (2017, Oktober). Analyzing the health risks resulting from extending the 400kV high voltage transmission lines on the human. *Tikrit Journal of Engineering Sciences*, 24(1), 89–95.
- Dianovský, R., Pecho, P., Veľký, P., & Hruz, M. (2023). Electromagnetic radiation from high-voltage transmission lines: Impact on UAV flight safety and performance. *Transportation Research Procedia*, 75, 209–218.

- Gao, Z., & Zhao, L. (2025, Agustus). Health impacts of cross-regional transmission infrastructure: Evidence from China's ultra-high voltage projects. *Energy Economics*, 148, 108669.
- Haryono, & Sudarti. (2013). Analisis faktor penyebab timbulnya keluhan kesehatan masyarakat di sekitar SUTET-500 KV. Repository Universitas Jember. <https://repository.unej.ac.id/handle/123456789/59017>
- IEEE Standards Association. (2022). *IEEE standard 2819-7641*. <https://standards.ieee.org/ieee/2819/7641/>
- Kachari, K. K., Santhakumar, E., Arunachalam, N., Yadam, Y. R., & Arunachalam, K. (2025). Near-field electromagnetic sensors for non-contact monitoring and workpiece classification during WEDM process. *IEEE Sensors Journal*.
- Kementerian Kesehatan RI. (2023, Maret 31). *Benarkah saluran udara tegangan ekstra tinggi (SUTET) berpengaruh pada kesehatan*. Yankes. https://yankes.kemkes.go.id/view_artikel/2084/benarkah-saluran-udara-tegangan-ekstra-tinggi-sutet-berpengaruh-pada-kesehatan
- Kementerian Kesehatan RI. (2023, Maret 31). *Benarkah saluran udara tegangan ekstra tinggi (SUTET) berpengaruh pada kesehatan*. Yankes. https://yankes.kemkes.go.id/view_artikel/2084/benarkah-saluran-udara-tegangan-ekstra-tinggi-sutet-berpengaruh-pada-kesehatan
- Lunca, E., Ursache, S., & Salceanu, A. (2018). Computation and analysis of the extremely low frequency electric and magnetic fields generated by two designs of 400 kV overhead transmission lines. *Measurement*, 124, 197–204.
- Nainggolan, D. V., Hindardi, & Yulianti, B. (2016). Analisis pengaruh efek kuat medan listrik saluran tegangan tinggi transmisi 70 kV–150 kV pada lingkungan perumahan. *Jurnal Teknik Industri*, 5(2).
- Ren, S., Bao, R., & Gao, Z. (2025, Februari). Arrival of distant power: The impact of ultra-high voltage transmission projects on energy structure in China. *Energy*, 316, 134527.
- Republik Indonesia. (2009). *Undang-Undang No. 30 Tahun 2009 tentang Ketenagalistrikan*. DPR RI. https://www.dpr.go.id/dokjdih/document/uu/UU_2009_30.pdf
- Resantie, L., & Santoso, E. B. (2020). Identifikasi pola perkembangan wilayah di Kabupaten Sidoarjo tahun 2009–2020. *Jurnal Teknik ITS*, 10(2).
- Ridhoi, R., & Wahid, A. (2017). *Limbah pabrik di delta Brantas: Industrialisasi dan permasalahan lingkungan di Sidoarjo Jawa Timur, 1950–2006*. Repository UGM.
- Rogger, D., & Somani, R. (2023). The persistent impact of electoral incentives on the quality of infrastructure. *Journal of Public Economics*, 222, 104880. <https://doi.org/10.1016/j.jpubeco.2023.104880>
- Sari, & Tani, M. (2016). *Prakiran kebutuhan energi listrik menggunakan support vector regression (SVR) dengan optimasi algoritma genetika (Studi kasus PLN Malang)*.
- World Health Organization. (2016). *Radiation: Electromagnetic fields*. WHO. <https://www.who.int/news-room/questions-and-answers/item/radiation-electromagnetic-fields>
- Yazdani-Asrami, M., Sadeghi, A., Song, W., Madureira, A., Murta-Pina, J., Morandi, A., & Parizh, M. (2022). Artificial intelligence methods for applied superconductivity: Material, design, manufacturing, testing, operation, and condition monitoring. *Superconductor Science and Technology*, 35(12), 123001.
- Yazdani-Asrami, M., Sadeghi, A., Song, W., Madureira, A., Murta-Pina, J., Morandi, A., & Parizh, M. (2022). Artificial intelligence methods for applied superconductivity: Material, design, manufacturing, testing, operation, and condition monitoring. *Superconductor Science and Technology*, 35(12), 123001.
- Zamanian, A., & Hardiman, C. J. H. F. E. (2005). Electromagnetic radiation and human health: A review of sources and effects. *High Frequency Electronics*, 4(3), 16–21.