

Performance Comparison of Busbar and Cable Based Electrical Network Systems

Cihan Burak Fırat¹ , Serap Cekli² , Cengiz Polat Uzunoğlu² 

¹Institute of Graduate Studies, İstanbul University-Cerrahpaşa, İstanbul, Türkiye

²Department of Electrical and Electronics Engineering, İstanbul University-Cerrahpaşa Faculty of Engineering, İstanbul, Türkiye

Cite this article as: C. Burak Fırat, S. Cekli and C. Polat Uzunoğlu, "Performance comparison of busbar- and cable-based electrical network systems," *Electrica*, 25, 0094, 2025. doi: 10.5152/electrica.2025.25094.

WHAT IS ALREADY KNOWN ON THIS TOPIC?

- Previous studies have investigated the magnetic fields, thermal behavior, contact resistance at connection points, and failure mechanisms of busbar systems.
- There are also various studies in the literature that compare busbar systems with cable systems in terms of performance and application.

WHAT DOES THIS STUDY ADD ON THIS TOPIC?

- In this study, various types of busbars and equivalent types of cables that can be used in similar applications were operated under the same conditions, and their thermal behavior, electrical performance, and magnetic fields were compared.

Corresponding author:

Cihan Burak Fırat

E-mail:

burak.firat@istanbul.edu.tr

Received: April 25, 2025

Revision Requested: May 15, 2025

Last Revision Received: May 16, 2025

Accepted: May 31, 2025

Publication Date: October 24, 2025

DOI: 10.5152/electrica.2025.25094



Content of this journal is licensed under a Creative Commons Attribution-NonCommercial 4.0 International License.

ABSTRACT

Nowadays, with the increase of high powered devices, there has been a significant increase in energy consumption. In order to meet the consumption demands and with the increase in the number of high-rise buildings, components such as cables and busbars are effectively used in supply networks. Busbars are frequently used power system elements compared to traditional cable systems that are prefabricated as modular for the transmission and distribution of electrical energy. In this study, classical cable systems and busbars are examined under a specified load, and their electrical performances are provided. Electrical parameters such as power, voltage drop, and THD (total harmonic distortion) of equivalent busbars and cables under load are obtained in terms of load capacity. Electromagnetic analyses are performed and the electromagnetic emission of these systems are analyzed. In addition, the temperatures caused by the increasing currents in the busbars and cables due to the specified loads are determined with a thermal camera. In addition, two operational buildings with similar power values and conductor quantities are examined. These busbar- and cable distribution-based buildings are compared in terms of voltage drop for certain distribution line lengths. In this study, experimental results for both cable and busbar systems are presented and comparisons are interpreted to select the optimum network type. The results suggest that busbars are preferable in high-current applications where reduced heating and voltage drops are critical, while cables may be more suitable in environments sensitive to electromagnetic interference.

Index Terms—Busbar, electrical network, EMF, THD

I. INTRODUCTION

Energy consumption is increasing rapidly due to the extensively produced products which are manufactured by innovative approaches and advances in technology. In addition, smart houses which promise an innovative environment in our lives increase electrical consumption day by day. Electricity transmission and distribution systems should be able to meet the increasing demand in this manner. The industry is also introducing new devices to their ecosystems in order to produce faster and error-free applications. This leads to changes in the areas where energy consumption occurs within the buildings and other constructions to create new lesser energy consumption points. In case of changes in energy consumption points, the installation of new cables creates additional costs and complexity. Busbars have been used in the United States since the 1930s to meet this need effectively [1].

A busbar is an effective tool for electrical energy transmission and distribution. The selected parameters—total harmonic distortion (THD), Electromagnetic Field (EMF), temperature, and voltage drop—are essential in evaluating the operational efficiency and reliability of power distribution systems. THD affects signal integrity, EMF influences safety and compliance, temperature impacts component lifespan, and voltage drop reflects energy loss and load performance. Unlike previous studies that focus on individual parameters, this work offers a holistic, side-by-side experimental comparison of busbar and cable systems under equivalent electrical and environmental conditions. A busbar consists of a conductive metal and an insulating material. The busbar system is formed by combining the busbar parts of different types of modules. Busbars

can be used in high buildings and industrial areas for energy transmission where this busbar can be interconnected for the desired length of distribution lines in the electrical grid [2-4].

The generation, transmission, and distribution sections of the electrical grid naturally cause energy loss on the lines which may lead to excessive power losses [5]. Due to the self-resistance of the energy transmission lines, a certain amount of potential difference occurs during transmission [6]. This is called voltage drop. When calculating voltage drop, the 220-216 V range is considered to be ideal for a single-phase 220 V distribution network [7]. In this study, the voltage drops of the equivalent cables and busbars were investigated by using Metrel Power Quality Analyzer Plus MI 2292.

In this study, the heating of the equivalent busbar and conventional cables at the specified current values chosen as the upper points of the endurance limits are investigated [8]. For this purpose, appropriate loads are connected to a single line and the current level is increased. The cable and busbar, which are started to heat up with the rising current are observed with Fluke thermal imager Ti32. In real life, users can use multiple sockets on a single line, causing excessive currents to flow. According to recent studies, the temperature increase affects the cable life as well as the voltage drop. A cable at 70°C ages 100 times faster than a cable at 10°C [9].

It is well established that electromagnetic fields may adversely affect human health. It has been observed that electromagnetic fields have triggering effects on diseases such as leukemia [10], cancer [11], Parkinson's [12], etc. Since a low-frequency range of 50–60 Hz is commonly used in the transmission and distribution of electrical energy, continuous exposure of people to this frequency is inevitable. The effect of electromagnetic fields on people and human health issues increases drastically [13]. In this study, electric field and magnetic field propagation for cable and busbars have been investigated with the aid of an Extech Multi-Field EMF meter (EMF 450) which can measure electric field and magnetic field at a specific distance.

The THD is a measurement of the harmonic distortion present in a signal and is defined as the ratio of the sum of the powers of all harmonic components to the power of the fundamental frequency

[14-16]. THD is also measured for both cables and Busbars for comparison purposes.

II. BUSBAR AND CONVENTIONAL CABLE SYSTEMS

A busbar is a modular energy transmission and distribution tool, which is formed by isolating current-carrying busbar conductors in a closed body. The busbar system is formed by combining the busbar parts of different types of modules. The output boxes are located at the desired intervals on the busbar system that provide safe energy connection points on the line [17].

One or more metal wires, which are coated with an insulating material that is used to conduct electrical current, are called cables [18, 19]. In this study, busbars and cables which contain copper and aluminum conductors are taken into consideration. The specifications for employed cables and busbars are given in Table I. All cables and busbars are selected to be 50 cm long, which ensures the reliability of the test results in the experiments.

Cable types and busbar types are given in Table I, which are used in the tests. The selected types were chosen based on rated current equivalence and widespread industrial usage, ensuring meaningful and realistic comparisons. Conductor cross-sectional areas, rated voltages, currents and frequencies, conductor types, and conductor quantities are specified as well. Type 1 Cable and Type 2 Busbar, Type 2 Cable and Type 3 Busbar, Type 3 Cable and Type 5 Busbar, and Type 4 Cable and Type 6 Busbar are selected equivalent to each other according to rated current.

III. TEST SETUP

The test setup is given in Fig. 1. In the experiments, measurements are obtained via a power analyzer with a resistive load for the busbar and cables. After the necessary protection units are located on the 220V main supply, a resistive load is connected to the busbar's output. The voltage level, current level, and THD of the system are measured with the power analyzer which was factory-calibrated to ensure measurement accuracy for the input and the output points of the busbars.

TABLE I. BUSBAR AND CABLE TYPES

	Conductor Cross Sectional Area (mm ²)	Rated Voltage (V)	Rated Current (A)	Rated Frequency (Hz)	Conductor Type	Conductor Quantity
Type 1 Busbar	330	1000	800	50	Aluminum	4
Type 2 Busbar	120	1000	160	50	Aluminum	4
Type 3 Busbar	47.25	690	100	50	Aluminum	4
Type 4 Busbar	330	1000	800	50	Aluminum	4
Type 5 Busbar	12.57	690	63	50	Copper	4
Type 6 Busbar	2.54	690	25	50	Copper	6
Type 1 Cable	35	1000	156	50	Copper	4
Type 2 Cable	16	690	98	50	Copper	4
Type 3 Cable	10	690	59	50	Copper	4
Type 4 Cable	2.5	690	25	50	Copper	3

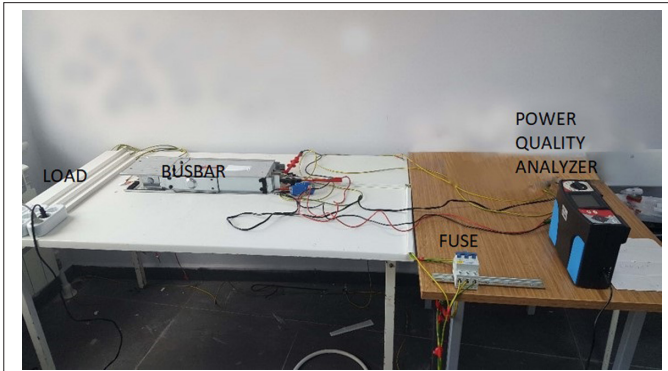


Fig. 1. Test setup.

The test diagram is shown in Fig. 2.

This test is repeated one by one for six types of busbars and four types of cables. The current, voltage, power, and THD values are recorded, which are simultaneously observed from the power quality analyzer. After the first part is completed, the measurement point is changed. The power analyzer is located at the point beyond the busbar/cable which is given in Fig. 3. For each of the six types of busbar and four types of cables, the power analyzer is connected to the point before the load. The current, voltage, power, and THD values obtained from the power analyzer are noted. It is aimed to observe the changes in voltage, current, and harmonic values on the busbar for the fixed conditions.

The next experiment is conducted for EMF measurements [20-23]. The EMF test setup is given in Fig. 4. The EMF meter (Extech EMF 450) used in this study was factory-calibrated. The EMF values represent typical operational conditions using 20A current, commonly encountered in real-life distribution scenarios. Electric field and magnetic field measurements are measured by placing an EMF meter 5 cm away from the busbar as seen in the figure when a fixed 20 A current is drawn by the single phase system which is supplied by the main voltage of the grid. Then the experiment is repeated for all six types of busbars and four types of cables. The gauge distance is kept constant for all tests.

In addition, thermal analysis tests are conducted in which a constant 25A current is provided for 10 minutes through the equivalent busbar and cable. After 10 minutes, the temperature at the joint and midpoints of the cables and busbars are examined with the help of the thermal imager.

IV. TEST RESULTS

Tests are conducted for fixed conditions such as measurement systems and ambient conditions for busbar and cable systems.

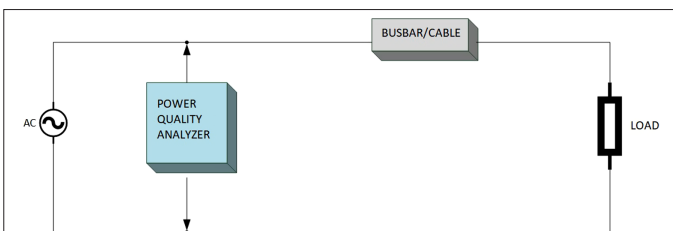


Fig. 2. Power quality analyzer connection to busbar/cable.

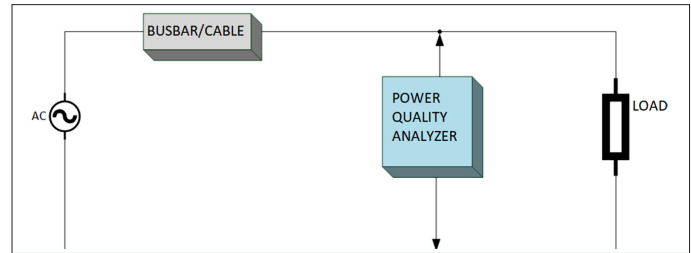


Fig. 3. Power quality analyzer connection to load.

A. Electrical Characteristics of Busbars and Cables

The experiments were carried out in the Laboratory at room temperature of approximately 20°C. The relative humidity of the laboratory is about 50%. The electrical characteristics of cable and busbar systems are given in Table II. Measurements are noted as voltage (U), current (I), active power (P), and total harmonic distortion (THD) for voltage and current. THD determines the signal quality of the power signal which represents harmonic disturbance on the fundamental power signal component (50 HZ). In these two equivalent transmission components, the voltage drop of the cable is observed to be higher than the voltage drops of the busbar on average. Type 3 and Type 2 cables have nearly equal rated currents. Table III shows that the THD in the busbar system is higher than that in the cable system.

Table II presents the electrical performance of Type 2 Busbar and Type 1 Cable systems under resistive load. Although both systems exhibit voltage drops, it is more pronounced in the cable. For instance, in phase R, the voltage drops from 221.8 V to 217.5 V for the cable, whereas it drops from 215.4 V to 214.1 V for the busbar. Additionally, the THD values observed in the cable are generally lower than those in the busbar.

Table III provides a comparison between Type 3 Busbar and Type 2 Cable systems, which have nearly equal current-carrying capacities. The results show that the cable system achieves higher active power values and slightly lower THD levels. Although voltage drops are comparable in both systems, THD values range between 1.6% and 2.4% for cables and between 2.2% and 2.5% for busbars.

Table IV shows the measurement values for the Type 5 Busbar and Type 3 Cable. Voltage drop is observed as higher for cable. Table V provides a single phase experiment which is done with single phase cable (Type 4) and busbar (Type 6). On the table, it is seen that the voltage drop in the busbar is higher than the voltage drop in the cable.

Experimental results for single-phase systems are summarized in Table V, comparing Type 6 Busbar and Type 4 Cable. The

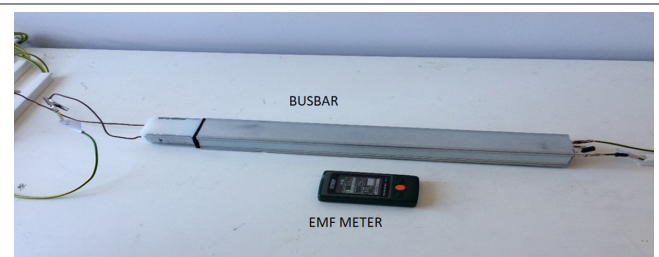


Fig. 4. Electric field and magnetic field experiment.

TABLE II. TYPE 2 BUSBAR AND TYPE 1 CABLE UNDER RESISTIVE LOAD

		Power Side				Load Side			
		U (V)	I (A)	P (W)	THD (U-I) (%)	U (V)	I (A)	P (W)	THD (U-I) (%)
Type 2 Busbar	R	215.4	8.957	1924.2	2.3–2.3	214.1	8.912	1902.6	2.6–2.4
	S	216.5	8.989	1939.9	2.3–2.4	215.6	8.956	1925.6	2.5–2.4
	T	214.9	8.939	1915.3	2.4–2.4	214.3	8.959	1923.3	2.4–2.4
Type 1 Cable	R	221.8	9.127	2017.0	1.6–2.1	217.5	9.012	1953.1	1.6–1.7
	S	223.5	9.166	2039.0	2.0–2.5	218.5	9.063	1971.1	1.7–2.2
	T	220.8	9.114	2003.1	2.2–2.4	216.8	9.011	1945.6	2.3–2.4

measurements indicate that both systems perform similarly in terms of electrical characteristics. However, the THD values are once again lower in the cable (ranging from 1.7% to 1.9%) compared to the busbar (ranging from 2.3% to 2.5%). While voltage drops do not differ significantly, the busbar offers a more stable transmission.

B. Electrical Field and Magnetic Field Measurement Results

Electric field and magnetic field results obtained from the tests are shown in Table VI. The left column shows the magnetic field and the right column shows the electrical fields. As seen in the table, the test device shows higher magnetic field values for busbars compared to the equivalent conventional cable.

C. Thermal Analysis Test Results

Thermal analysis tests are conducted by using a Fluke thermal imager Ti32 infrared camera.

As seen in Fig. 5, the temperature increases up to about 80°C at the cable joints, while the highest temperature seen at the joint point of the busbar is about 29.8°C, which is given in Fig. 6. The temperatures at the midpoints of the cable and busbar are also measured. The observed thermal differences suggest that busbar systems may offer a longer operational lifespan and lower maintenance frequency, as elevated temperatures in cables accelerate insulation degradation. The midpoint of the cable is about 36°C, while the midpoint of the busbar is about 23°C. The room temperature at which the experiments are performed is 20°C.

D. Operational Building Analysis

In a chosen building using a busbar system, measurements are conducted on the distribution line from the main distribution board to

the specific floor distribution board. The distance between the main distribution board and the floor distribution board is approximately 38 m. The measurements are fulfilled for another building which has approximately 22 meters of cable system for comparison. It is not possible to find identical buildings in terms of distribution line lengths, however, the measurements are calculated based on their line length ratios. The voltage drop readings for the three-phase distributed operational buildings are given below:

Voltage levels for 38 m long busbar line in the building:

- When 71A current is passing through line L1, the voltage has decreased from 229 V to 227.5 V.
- When 69 A current is passing through line L2, it has decreased from 229 V to 227.5 V.
- When 72 A current is passing through line L3, the voltage has decreased from 228 V to 227.3 V.
- Voltage levels for 152 m long busbar line in the same building:
- When 63 A current passes through line L1, it has decreased from 232 V to 224.9 V.
- When 69 A current passes through line L2, it has decreased from 231 V to 225.1 V.
- When the 72 A current is passing through line L3, it has decreased from 229 V to 225.8 V.

A building that uses cable and draws approximately equivalent current has been selected.

- 22 meters long cable line in another operational building:
- When 66 A current is passing through line L1, it has decreased from 226 V to 224.9 V.

TABLE III. TYPE 3 BUSBAR AND TYPE 2 CABLE UNDER RESISTIVE LOAD

		Power Side				Load Side			
		U (V)	I (A)	P (W)	THD (U-I) (%)	U (V)	I (A)	P (W)	THD (U-I) (%)
Type 3 Busbar	R	215.5	8.950	1923.6	2.5–2.4	214.6	8.928	1909.5	2.3–2.4
	S	216.5	8.980	1937.7	2.5–2.5	215.9	8.963	1930.6	2.4–2.3
	T	216.7	8.989	1941.3	2.2–2.3	216.5	8.980	1937.7	2.3–2.3
Type 2 Cable	R	217.9	9.029	1960.3	1.7–1.7	217.1	9.011	1950.0	1.6–1.8
	S	218.7	9.078	1974.9	2.0–2.4	218.7	9.061	1971.8	2.0–2.3
	T	216.5	9.011	1942.2	1.9–2.2	216.8	9.000	1942.1	2.1–2.2

TABLE IV. TYPE 5 BUSBAR AND TYPE 3 CABLE UNDER RESISTIVE LOAD

		Power Side				Load Side			
		U (V)	I (A)	P (W)	THD (U-I) (%)	U (V)	I (A)	P (W)	THD (U-I) (%)
Type 5 Busbar	R	215.3	8.931	1917.8	2.3–2.4	215.2	8.947	1920.5	2.4–2.4
	S	215.6	8.950	1923.4	2.4–2.6	215.5	8.959	1925.4	2.5–2.5
	T	214.4	8.919	1907.2	2.3–2.5	214.3	8.928	1910.1	2.3–2.3
Type 3 Cable	R	217.7	9.020	1957.0	1.6–1.7	217.4	9.040	1967.5	1.9–1.9
	S	218.8	9.066	1973.3	2.0–2.2	218.2	9.075	1983.2	2.1–2.3
	T	216.9	9.003	1943.6	2.1–2.1	216.2	9.026	1956.7	2.3–2.4

TABLE V. TYPE 6 BUSBAR AND TYPE 4 CABLE UNDER RESISTIVE LOAD

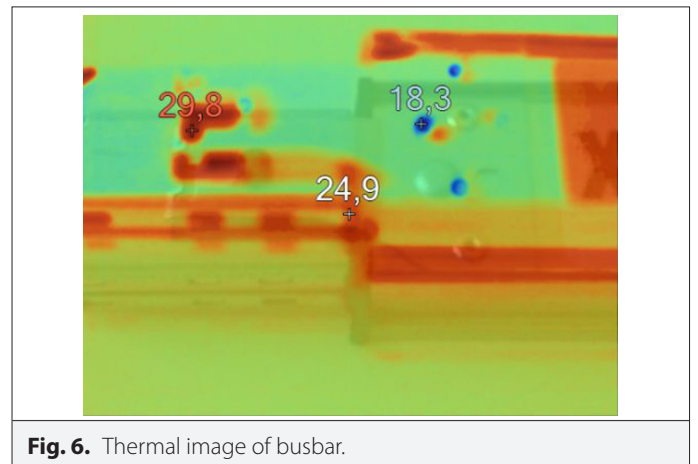
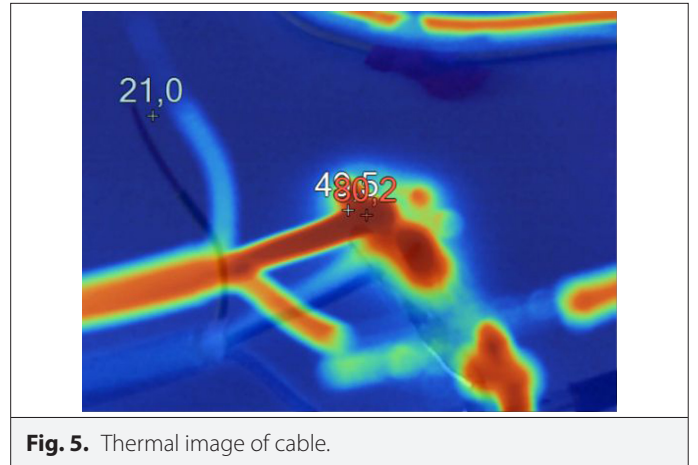
	Power Side				Load Side			
	U (V)	I (A)	P (W)	THD (U-I) (%)	U (V)	I (A)	P (W)	THD (U-I) (%)
Type 6 Busbar	216.1	8.956	1928.8	2.5–2.4	215.1	8.954	1926.2	2.3–2.4
Type 4 Cable	216.5	8.965	1933.1	1.7–1.8	216.0	8.953	1927.2	1.7–1.9

TABLE VI. ELECTRIC FIELD AND MAGNETIC FIELD RESULTS OF CABLES AND BUSBARS

Type	Magnetic Field (mG)	Electrical Field (V/m)
Type 1 Busbar	125.0	387
Type 2 Busbar	69.4	49
Type 3 Busbar	76.0	153
Type 4 Busbar	40.7	248
Type 5 Busbar	53.3	160
Type 6 Busbar	61.9	453
Type 1 Cable	43.7	126
Type 2 Cable	44.8	259
Type 3 Cable	28.5	116
Type 4 Cable	20.1	178

- When 54 A current is passing through line L2, the voltage has decreased from 225 V to 224 V.
- When 79 A current is passing through line L3, the voltage has decreased from 224 V to 222.4 V

According to the operational building results it is observed that a busbar-operated building with a 152 m long busbar line has an average voltage drop of 5.33 V for an average of 68 A current. In addition, the same busbar-operated building with a 38 m long busbar line has an average voltage drop of 1.3 V for an average of 70 A current. On the other hand, another cable-operated building with a 22 m long conventional cable line has an average voltage drop of 1.2 V for an average of 66 A current. For a cable distributed line it should be approximately 8.3 V for 152 m and 2.07 V for 38 m layout. So it



could be concluded that cable systems are prone to generate higher voltage drops than the busbar systems.

VI. CONCLUSION

In this study comparison of conventional cable distribution systems and busbar-based distribution systems are compared for different physical conditions. A test setup is employed to investigate different parameters such as voltage drop, EMF analysis, and heating analysis. Equivalent busbar and cable sections (equal length) are employed to fulfill proper comparison. According to the EMF measurements presented, the magnetic field measurement near the busbar is higher than the cables of similar value. It is reasonable to use cables in structures where electromagnetic interference is vital. The busbar systems are less heated under higher currents than conventional cable distribution systems. When higher current values are applied at the limits of the electrical transmission and distribution components, it is observed that the busbar-based systems are more durable than the cable systems in terms of temperature rise. The temperature of the busbar at the joint points is observed as 29.8°C, while the temperature is observed at approximately 80°C in conventional cables. Therefore, the busbar provides a thermal difference of 37.5% when compared to conventional cable. This is important in reducing common fires caused by electrical contact. Voltage drop in the internal electrical grid may cause problems for the operation of devices. Therefore, voltage drops were analyzed through the experiments. It is observed that the voltage drop in busbar systems is approximately 20% less when compared to cable-based systems according to the tests and voltage drop measurements in operational buildings which are supplied by busbar and cable systems. Based on the results, busbars are recommended for high-load, long-distance, or heat-sensitive environments, while cables may be preferred where electromagnetic exposure must be minimized.

Data Availability Statement: The data that support the findings of this study are available on request from the corresponding author.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – C.B.F.; Design – C.B.F., S.C.; Supervision – C.P.U., S.C.; Resources – C.B.F., C.P.U.; Materials – C.P.F.; Data Collection and/or Processing – S.C., C.B.F.; Analysis and/or Interpretation – S.C.; Literature Search – C.B.F., S.C.; Writing – C.P.U., C.H.F.; Critical Review – S.C., C.P.U.

Declaration of Interests: The authors have no conflicts of interest to declare.

Funding: The authors declare that this study received no financial support.

REFERENCES

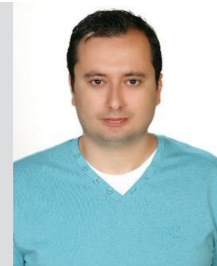
1. S. L. Ho, Y. Li, X. Lin, H. C. C. Wong, and K. W. E. Cheng, "A 3-D study of eddy current field and temperature rises in a compact bus duct system," *IEEE Trans. Magn.*, vol. 42, no. 4, pp. 987–990, 2006. [\[CrossRef\]](#)
2. S. P. Kalane, and C. M. Bobade, "Comparative analysis of reactance of three phase busbar trunking system," *Int. J. Eng. Technol. Sci. Res.*, vol. 5, no. 4, pp. 614–619, 2018.
3. IEC, *IEC 61439-6: Low-Voltage Switchgear and Controlgear Assemblies - part 6: Busbar Trunking Systems (Busways)*, 2012.
4. Q. Ge, Z. Li, S. Liu, and J. Xing, "Formulas calculating the reactance of tubular busbars and their derivation in primary electrical connection schemes," *Sci. Rep.*, vol. 13, no. 1, p. 3223, 2023. [\[CrossRef\]](#)
5. G. Mazzanti, and M. Marzinotto, "Relationship between the expressions for electrical resistivity and the field profiles in HVDC cable insulation," In *IEEE Conference on Electrical Insulation and Dielectric Phenomena (CEIDP)*. New York: IEEE, 2016, pp. 947–950. [\[CrossRef\]](#)
6. J. W. Fourie, and J. E. Calmeyer, "A statistical method to minimize electrical energy losses in a local electricity distribution network," In *IEEE Africon. 7th African Conference in Africa (IEEE Cat. No. 04CH37590)*, Vol. 2. New York: IEEE, 2004. [\[CrossRef\]](#)
7. O. A. Osahenvenwen, and O. Omorogiwa, "Parametric modeling of voltage drop in power distribution networks," *Int. J. Tech. Res. Appl.*, vol. 3, no. 3, pp. 356–359, 2015.
8. S. Li, Y. Han, and C. Liu, "Coupled multiphysics field analysis of high-current irregular-shaped busbar," *IEEE Trans. Compon. Packaging Manuf. Technol.*, vol. 9, no. 9, pp. 1805–1814, 2019. [\[CrossRef\]](#)
9. E. Kroener, G. S. Campbell, and M. Bittelli, "Estimation of thermal instabilities in soils around underground electrical power cables," *Vadose Zone J.*, vol. 16, no. 9, pp. 1–13, 2017. [\[CrossRef\]](#)
10. A. Nguyen, C. M. Crespi, X. Vergara, and L. Kheifets, "Pesticides as a potential independent childhood leukemia risk factor and as a potential confounder for electromagnetic fields exposure," *Environ. Res.*, vol. 238, no. 1, 116899, 2023. [\[CrossRef\]](#)
11. S. C. Chow, Y. Zhang, R. W. M. Ng, S. R. Hui, I. A. Solov'yov, and W. Y. Lui, "External RF-EMF alters cell number and ROS balance possibly via the regulation of NADPH metabolism and apoptosis," *Front. Public Health*, vol. 12, 1425023, 2024. [\[CrossRef\]](#)
12. A. Huss, T. Koeman, H. Kromhout, and R. Vermeulen, "Extremely low frequency magnetic field exposure and Parkinson's disease—A systematic review and meta-analysis of the data," *Int. J. Environ. Res. Public Health*, vol. 12, no. 7, pp. 7348–7356, 2015. [\[CrossRef\]](#)
13. European Commission, *Potential Health Effects of Exposure to Electromagnetic Fields (EMF)*, 2015a. [\[CrossRef\]](#)
14. H. Anga, S. Gite, S. Bhavne, and S. Divya, "Power factor and harmonic analysis in single phase AC to DC converter," *Int. J. Eng. Res. Technol. (IJERT)*, vol. 4, no. 04, 2015.
15. Y. Babacan, C. P. Uzunoğlu, S. Cekli, F. Kaçar, and M. Uğur, "Wavelet analysis of a memristor emulated model proposed for compact fluorescent lamp operated systems," *Electr. Power Syst. Res.*, vol. 160, pp. 56–62, 2018. [\[CrossRef\]](#)
16. T. Abbas, N. Khan, and M. S. Afzal, "A novel diode rectifier with a series connected chopper for reduced input current thd," *Iran. J. Sci. Technol. Trans. Electr. Eng.*, vol. 48, no. 2, pp. 831–846, 2024. [\[CrossRef\]](#)
17. S. P. Kalane, and C. M. Bobade, "Comparative analysis of electrical parameters for three phase busbar trunking system," *Int. J. Sci. Res. Scienceand Technol.*, vol. 4, no. 5, pp. 1698–1709, 2018.
18. E. Napieralska-Juszczak, K. Komez, F. Morganti, J. K. Sykulski, G. Vega, and Y. Zeroukhi, "Measurement of contact resistance for copper and aluminium conductors," *Int. J. Appl. Electromagn. Mech.*, vol. 53, no. 4, pp. 617–629, 2017. [\[CrossRef\]](#)
19. E. Eroglu, I. Guney, I. Gunes, and E. Sener, "Mathematical modeling of heat effect on cable insulation," *Acta Phys. Pol. A*, vol. 131, no. 3, pp. 539–542, 2017. [\[CrossRef\]](#)
20. I. Kolcunová *et al.*, "Influence of electromagnetic shield on the high frequency electromagnetic field penetration through the building material," *Acta Phys. Pol. A*, vol. 131, no. 4, pp. 1135–1137, 2017. [\[CrossRef\]](#)
21. S. C. Yener, and O. Cerezci, "Material analysis and application for radio frequency electromagnetic wave shielding," *Acta Phys. Pol. A*, vol. 129, no. 4, pp. 635–638, 2016. [\[CrossRef\]](#)
22. A. Zhukov *et al.*, "Engineering of magnetic properties of magnetic microwires," *Acta Phys. Pol. A*, vol. 133, no. 3, pp. 321–328, 2018. [\[CrossRef\]](#)
23. S. Sharma, A. Kumar, and O. P. Thakur, "Nd modified BiFeO₃ perovskites: Investigations on their structural, and magnetic properties," *Indian J. Eng. Mater. Sci.*, vol. 30, no. 5, pp. 729–734, 2023.



Cihan Burak Firat graduated from Vefa Anatolian High School in 2006 and began his undergraduate studies in the Electronics Engineering Department at Istanbul University in the same year. He earned his M.Sc degree in Electrical Electronics Engineering from Istanbul University, Istanbul, Turkey, in 2019. Currently, he is pursuing a Ph.D. in Electrical and Electronics Engineering at Istanbul University-Cerrahpaşa. He is in the thesis stage of his doctoral studies. In addition to his academic endeavors, he works as an engineer at Istanbul University, contributing to various projects in the field of electrical engineering. His research interests primarily include power systems, electrical energy, and artificial intelligence.



Serap Cekli received her BSc. degree in Electronics Engineering from Istanbul University in 2000, MSc. degree in Electronics and Communication Engineering from Istanbul Technical University in 2003. She has received PhD. degree from Istanbul University Electrical-Electronics Engineering Department in 2009. She worked for Istanbul University Electrical-Electronics Engineering Department as a Research Assistant between 2001-2009. She worked for Maltepe University, Computer Engineering Department between 2009-2021. She is currently working in Istanbul University - Cerrahpaşa Electrical-Electronics Engineering Department. Her research interests are digital systems design, SoC design, signal processing, digital architectures.



Cengiz Polat Uzunoğlu graduated from Vefa Anatolian High School in 1998 and started his undergraduate education at Istanbul University, Electronics Engineering Department in the same year. He received the M.Sc. and Ph.D. degrees in Electrical Electronics Engineering from Istanbul University, Istanbul, Turkey, in 2005 and 2011, respectively. He is currently working as a Professor in İstanbul Üniversitesi-Cerrahpaşa, Electrical and Electronics Engineering Department. Additionally, he currently serves as vice chair of the department. His main research interests include power systems, electrical energy, chaotic systems and high voltage engineering.