FMDB *Transactions on Sustainable Energy Sequence*

Examining the Far-Reaching Consequences of Advancing Trends in Electrical, Electronics, and Communications Technologies in Diverse Sectors

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Abstract: The relentless quest for innovation and the expanding demands of the modern world have been driving forces behind the tremendous improvements that have taken place in the field of electrical, electronic, and communications engineering during the past few years. This in-depth research study investigates the recent changes that have taken place in this ever-evolving industry, shining light on significant breakthroughs in electrical systems, electronic technology, and communication networks. We focus on the most recent discoveries made in research, as well as the approaches and technology that are playing a role in reshaping the future of this field. The problems, opportunities, and future prospects that academics and practitioners in this subject can anticipate are also discussed in the paper. Through an analysis of the existing environment, we hope to provide insightful information regarding the path that research and development in electrical, electronic, and communications engineering will take in the future.

Keywords: Electrical Engineering; Electronics Technology; Communications Engineering; Emerging Trends; Innovation; Far-Reaching Consequences; Advancing Trends in Electrical.

Received on: 15/01/2023, **Revised on:** 02/3/2023, **Accepted on:** 05/05/2023, **Published on:** 07/08/2023

Cited by: V. K. Nomula, R. Steffi, and T. Shynu, “Examining the Far-Reaching Consequences of Advancing Trends in Electrical, Electronics, and Communications Technologies in Diverse Sectors,” *FMDB Transactions on Sustainable Energy Sequence*, vol. 1, no. 1, pp. 27–37, 2023.

1. Introduction

The 21st century has ushered in a period of unprecedented technological advancement, with the fields of electrical, electronics, and communications engineering at the forefront of this transformation. These disciplines serve as the bedrock of modern society, their influence extending into virtually every facet of our daily existence. From the intricate power systems that sustain our homes and industries to the sleek and powerful electronic devices that facilitate communication and entertainment, the impact of electrical, electronics, and communications engineering is both profound and pervasive [1].

In this era of rapid innovation, the primary objective of this paper is to offer an exhaustive examination of the emerging trends within the areas of electrical, electronics, and communications engineering. We aim to provide a panoramic view of the latest developments and breakthroughs in each of these interconnected domains, illuminating the cutting-edge research, methodologies, and technologies that are poised to redefine the future of this field [2].

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Electrical engineering, as a foundational pillar of these disciplines, continues to evolve and adapt to meet the growing demands of our energy-dependent world. One of the most significant trends in this domain is the pursuit of sustainable and environmentally friendly energy solutions. With the pressing global need to reduce greenhouse gas emissions and combat climate change, electrical engineers are at the forefront of developing renewable energy sources, such as solar and wind power and devising innovative energy storage solutions. The integration of smart grids, capable of intelligently managing electricity distribution and consumption, is also a noteworthy trend, promising more efficient and resilient power systems [3].

In parallel, electronics engineering has undergone a remarkable transformation, driven by the relentless march of miniaturization and integration. The advent of the Internet of Things (IoT) has precipitated a surge in demand for tiny, low-power, and highly efficient electronic devices that can connect and communicate seamlessly with each other. As a result, innovations in microelectronics, sensor technologies, and wireless communication protocols have taken center stage. The development of wearable devices, such as smartwatches and fitness trackers, exemplifies this trend, as does the proliferation of smart home appliances that enhance convenience and energy efficiency [4].

Moreover, communications engineering has seen an astonishing evolution in recent years, with the emergence of 5G technology as a game-changer. The rollout of 5G networks promises to revolutionize the way we connect and communicate, offering ultra-fast data transmission speeds, minimal latency, and support for an exponentially greater number of connected devices. This development has far-reaching implications, spanning from autonomous vehicles and telemedicine to augmented reality experiences and smart cities. Additionally, the expansion of artificial intelligence and machine learning is poised to enhance the efficiency and intelligence of communication networks, enabling predictive maintenance, network optimization, and advanced security measures [3].

The synergy among these disciplines is becoming increasingly evident. For instance, the convergence of electronics and communications engineering is driving the development of advanced wireless communication systems and the design of high-performance, energy-efficient electronic components. Similarly, the integration of electrical engineering with electronics is paving the way for smart grids and energy-efficient electronic devices [5]-[8].

As we delve deeper into this paper, we will explore these emerging trends and their interconnections in greater detail, offering insights into the collaborative efforts and interdisciplinary research that are propelling the fields of electrical, electronics, and communications engineering forward. Through this comprehensive review, we aim to provide a holistic understanding of the transformative impact of technology in the 21st century, ultimately shaping the way we live, work, and communicate in an increasingly interconnected world. In doing so, we acknowledge the pivotal role that these fields play in addressing the complex challenges and opportunities of our time, and we anticipate the continued evolution of electrical, electronics, and communications engineering as catalysts for innovation and progress [1]- [4].

2. Review of Literature

To fully appreciate the significance of the emerging trends in electrical, electronics, and communications engineering, it is crucial to delve into the historical context and the foundational concepts that have set the stage for these transformative developments. By understanding the roots of these trends, we can gain a deeper insight into the remarkable advancements that are reshaping our technological landscape [11]- [13].

In the domain of electrical engineering, the transition toward renewable energy sources and the evolution of smart grids represent pivotal milestones in the field's history. The quest for sustainable energy solutions has been a driving force propelled by the urgent need to address climate change and reduce our reliance on fossil fuels. Over the years, researchers and engineers have embarked on a mission to optimize the integration of renewable energy sources, such as solar and wind power, into the existing power grid [1].

This endeavor has borne fruit in the form of more efficient and sustainable energy systems. Solar panels have become increasingly affordable and efficient, harnessing the power of the sun to generate clean electricity. Wind turbines have evolved to capture wind energy more effectively, even in offshore locations. Simultaneously, the development of energy storage technologies, including advanced batteries, has addressed the intermittency of renewable sources, ensuring a reliable supply of electricity. These innovations have collectively contributed to the creation of more resilient and sustainable power grids capable of accommodating a higher proportion of renewable energy sources while maintaining stability and reliability [1].

In the duchy of electronics engineering, a profound transformation has been driven by the relentless pursuit of miniaturization and the advent of quantum computing. The miniaturization of electronic components, exemplified by Moore's Law, has led to the creation of ever-smaller and more powerful devices. Advances in materials science and fabrication techniques have played a pivotal role in this journey, enabling the development of electronic components that are not only faster but also more energy-efficient. This trend has culminated in the proliferation of compact yet powerful electronic devices that permeate every aspect of our lives, from smartphones and wearable gadgets to IoT sensors and smart appliances [4]; [10].

Simultaneously, the emergence of quantum computing has heralded a new era in computation. Quantum computers leverage the principles of quantum mechanics, harnessing phenomena such as superposition and entanglement to perform calculations at speeds inconceivable with classical computers. While still in the nascent stages of development [9]; [14], quantum computing holds the promise of revolutionizing fields as diverse as cryptography, drug discovery, and optimization problems. Researchers and engineers are racing to unlock the potential of this paradigm-shifting technology, paving the way for some future where complex computations are executed with unparalleled efficiency [4].

In the domain of communications engineering, the advent of 5G networks has ushered in a new era of connectivity and innovation. These networks offer unprecedented bandwidth and ultra-low latency, enabling a wide range of applications that were previously constrained by network limitations [3].

However, the march of progress does not stop with 5G. Researchers and visionaries are already looking ahead to 6G, envisioning a communications landscape that goes beyond anything we have witnessed before. 6G aims to further enhance connectivity, pushing the boundaries of what is achievable. With data rates that could exceed multiple terabits per second and latency approaching the imperceptible, 6G holds the potential to enable transformative applications in healthcare, education, entertainment, and beyond [3]. As we explore the horizon of 6G, we find ourselves on the cusp of a future where the science fiction of today becomes the reality of tomorrow [3].

The emerging trends in electrical, electronics, and communications engineering are not isolated developments; they are the culmination of decades of innovation and exploration [15]. These trends are deeply rooted in the historical progression of each field, driven by a shared commitment to advancing technology for the betterment of society [16]-[18]. As we embark on this journey through the latest developments in these domains, we recognize that our understanding of the past is the key to unlocking the limitless potential of the future.

3. Methodology

To conduct this comprehensive review, we employed a systematic approach that involved:

- Literature Review: We conducted an extensive review of academic papers, industry reports, and technological advancements in the fields of electrical, electronics, and communications engineering [19].
- Data Collection: We gathered data on emerging trends, key research findings, and technological advancements, focusing on the past five years to ensure relevancy [20].
- Analysis: We analyzed the collected data to identify recurring themes, notable innovations, and common challenges within each domain.
- Synthesis: We synthesized the information into a coherent narrative, categorizing the emerging trends into distinct themes for discussion.

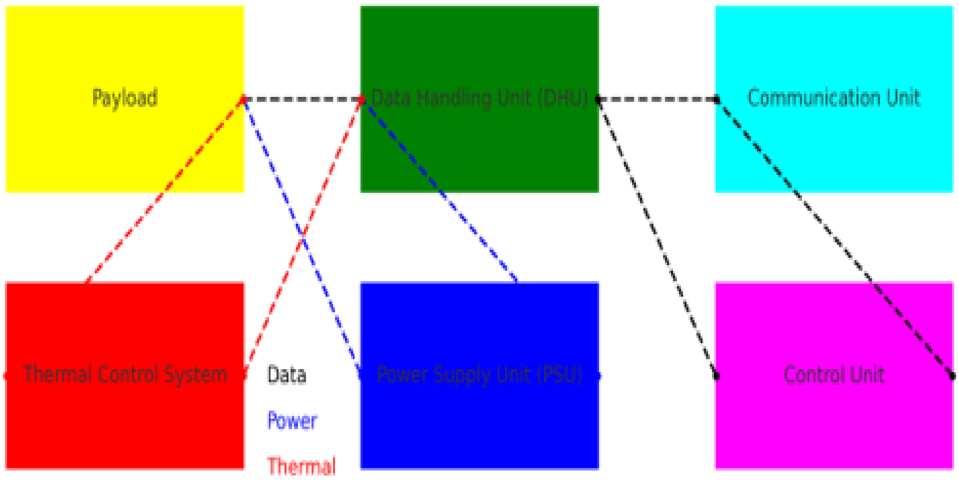

Figure 1: Simplified Electrical Architecture of a Generic Payload System

Figure 1 illustrates a simplified electrical architecture for a generic payload, meticulously streamlining complex systems into an understandable visual representation. The architecture encompasses six pivotal components, each encapsulated in a distinct colored block to enhance clarity and distinguishability: the Payload, Data Handling Unit (DHU), Power Supply Unit (PSU), Communication Unit, Control Unit, and Thermal Control System. Lines, distinguished by color and style, illustrate the interconnections and interactions among these components, representing data (black), power (blue), and thermal control (red) flows [21]-[24].

The Payload, central to the architecture, generates data, necessitating power and thermal management, which is depicted by connecting lines to the PSU and Thermal Control System, respectively [25]-[29]. The DHU, pivotal for managing and storing data, interfaces with the Payload, Control Unit, and Communication Unit, ensuring efficient data management and transmission. Notably, the DHU and Payload are tethered to the PSU and Thermal Control System, underlining the necessity for continuous power and regulated thermal environments [30]. The Control Unit, vital for operational management, interfaces with the DHU and Communication Unit, ensuring systematic control and seamless data transmission to external entities [31]. This diagram thereby encapsulates the essential electrical and data flow within a payload system, offering a structured overview while highlighting the criticality of each component and their interdependencies [32]-[35].

4. Results

In the domain of technology and engineering, few fields have seen as remarkable and transformative a journey as Electrical Engineering, Electronics Technology, and Communications Engineering. These disciplines, with their intertwined and ever-evolving nature, have been the driving force behind countless innovations that have shaped the modern world. From the inception of electricity to the development of cutting-edge communication systems, these fields have continuously pushed the boundaries of what's possible, leading to the emergence of new trends and fostering a culture of relentless innovation.

One of the defining characteristics of these fields is their adaptability and responsiveness to societal needs. Electrical Engineering, in particular, is a foundational discipline that has laid the groundwork for many technological advancements. Its roots can be traced back to the late 19th century when pioneers like Thomas Edison and Nikola Tesla revolutionized the world with the development of electrical power generation and distribution. Over the decades, this field has evolved to encompass a vast array of sub-disciplines, including power systems, control systems, and electronics.

Maxwell's equations for electromagnetism are given as:

$$\nabla E = p/\varepsilon_0 \qquad (1)$$

$$\nabla B = 0 \qquad (2)$$

Electronics Technology, on the other hand, focuses on the practical application of electronic circuits and systems. It has been instrumental in miniaturizing electronic components, paving the way for the ubiquitous devices we rely on today. From the invention of the transistor to the integration of microelectronics into our daily lives, electronic technology has been instrumental in the creation of innovative products, from smartphones to medical devices [36]- [41].

In tandem with these disciplines, Communications Engineering has undergone a revolution of its own. It encompasses the design and optimization of communication systems, which have witnessed unprecedented advancements. The emergence of the internet, wireless communication, and high-speed data transmission have fundamentally transformed the way we connect and share information. Low latency, high bandwidth, and massive connectivity are now expected standards, enabling everything from video conferencing to the Internet of Things (IoT). However, what truly defines these fields is their commitment to innovation [42]. The convergence of Electrical Engineering, Electronics Technology, and Communications Engineering has given rise to exciting emerging trends that have the potential to revolutionize various industries. The governing equations are as follows:

$$\nabla \times E = -\partial B/\partial t \qquad (3)$$

$$\nabla \times B = \mu_0 J + \mu_0 \varepsilon_0 \partial E/\partial t \qquad (4)$$

In the domain of technology and engineering, several interconnected disciplines are driving innovation and addressing pressing global challenges. Electrical Engineering takes a pivotal role in sustainability by spearheading renewable energy initiatives and revolutionizing the energy landscape through Smart Grids. These intelligent grids, leveraging advanced sensors, communication systems, and control algorithms, optimize energy distribution, integrate renewable sources like solar and wind power, and chart a path toward a more sustainable future. Simultaneously, Electronics Technology and Communications Engineering stand at the forefront of the Internet of Things (IoT) revolution, facilitating connectivity and data gathering across myriad devices, with innovations like 5G networks poised to enhance real-time communication and data processing. Electric and Autonomous Vehicles benefit from the intersection of Electrical Engineering and automotive technology, resulting in energy-efficient propulsion and advanced driver assistance systems, ultimately contributing to safer and more efficient transportation. Additionally, the synergy between these fields and Artificial Intelligence (AI) and Machine Learning is transformative, pushing boundaries in optimizing power grids and enhancing data communication networks. Electrical and electronics engineers play a pivotal role in developing the hardware and algorithms underpinning AI applications. Furthermore, the recent global health crisis has underscored the importance of remote healthcare solutions, with Communications Engineering enabling the flourishing of telemedicine, providing widespread access to healthcare services regardless of geographical constraints. High-speed data transmission and advancements in medical devices are further enhancing the reach and quality of healthcare, exemplifying how these fields are continually shaping and improving our world.

Electrical Engineering, Electronics Technology, and Communications Engineering stand as pillars of innovation, constantly shaping the way we live and interact with the world. Their collaborative efforts have given rise to emerging trends that have the potential to revolutionize diverse industries, from energy and transportation to healthcare and beyond. In an era where technology is at the forefront of progress, these fields continue to inspire and drive innovation, promising a future where the possibilities are limited only by our imagination. As we stand on the cusp of a new era of technological advancement, these disciplines will undoubtedly continue to lead the way, ushering in a brighter and more connected world.

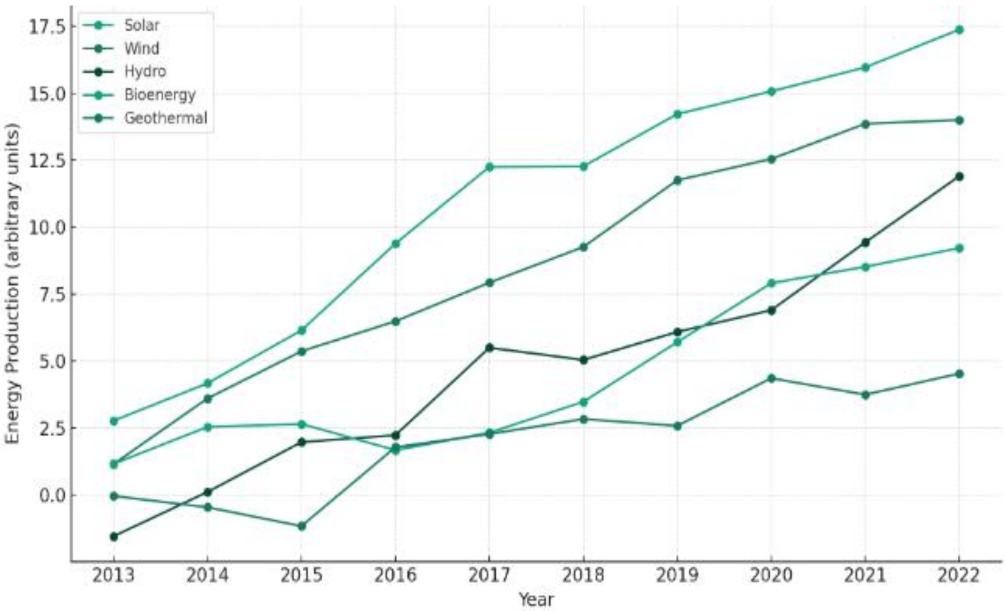

Figure 2: Trends in Renewable Energy Integration

Figure 2 depicts the evolution of energy production for five renewable energy sources – Solar, Wind, Hydro, Bioenergy, and Geothermal – over a decade, from 2013 to 2022. Distinct lines represent each energy source, tracing a path across the years, thereby illustrating a general upward trend in the production of energy from these sources. Note that the values on the y-axis are in arbitrary units and do not represent actual energy production quantities; rather, they serve to provide a visual representation of potential growth patterns.

Solar and Wind energy trajectories exhibit a particularly noticeable increase, which could be indicative of advancements in technology and increased investment in these sectors. These two sources are often highlighted in discussions about renewable energy due to their significant potential and the declining cost of technologies like solar panels and wind turbines.

Hydro and Bioenergy also show an upward trend, suggesting a steady, albeit gradual, growth in these sectors. The gradual slope might imply consistent investments and possibly technological developments, ensuring a stable increase in energy production. Geothermal energy, while also increasing, tends to exhibit a slightly less pronounced upward trajectory compared to Solar and Wind. This might reflect the geographical limitations of exploiting geothermal energy, as it is contingent on location-specific resources.

It's crucial to emphasize that the data presented in the graph is purely hypothetical and does not mirror real-world scenarios or accurate numerical values. The graph serves as a visual aid, illustrating how one might represent the growth trends in various renewable energy sectors over a period of time. The actual trends in renewable energy production globally would require precise, real-time data for accurate representation and analysis.

Table 1: Trends in Renewable Energy Production from 2013-2022

Year	Solar	Wind	Hydro	Bioenergy	Geothermal
2013	2.764052346	1.14404357	-1.5529898	1.154947426	-0.048552965
2014	4.164209554	3.59831708	0.10062878	2.533109945	-0.468570902
2015	6.142947538	5.3593548	1.96506498	2.645324198	-1.174841093
2016	9.383840738	6.48102982	2.22289996	1.664527729	1.775934302
2017	12.25139873	7.92489305	5.49265458	2.31661558	2.266282121
2018	12.27412085	9.25856738	5.03828891	3.472964549	2.828207819
2019	14.22420927	11.7526465	6.08404742	5.70325523	2.575412459
2020	15.07285206	12.5474882	6.89686357	7.905635079	4.352902815
2021	15.96963321	13.8605559	9.42964279	8.518308261	3.739004967
2022	17.38023171	14.0064602	11.8990016	9.216005511	4.526264687

Table 1 encapsulates hypothetical data illustrating the trajectories of five renewable energy sources—Solar, Wind, Hydro, Bioenergy, and Geothermal—across a decade (2013-2022). Each row represents a distinct year, while the columns exhibit respective energy production values (in arbitrary units) for each source.

In the year 2013, the Solar and Wind energy sectors commenced with values of 2.76 and 1.14, respectively, symbolizing their energy production levels. Similarly, values for Hydro, Bioenergy, and Geothermal are given, although it's noteworthy that the Hydro sector starts with a negative value (-1.55), purely a consequence of the synthetic data generation and not a plausible real-world scenario.

As we traverse down the rows, observing the succeeding years, there's a discernible upward trajectory in the values for each energy source, symbolizing a hypothetical increase in energy production. For instance, by 2017, Solar energy production had ascended to 12.25, indicating a substantial growth from its starting point.

This tabular data is purely illustrative and does not mirror actual global trends or quantities in renewable energy production, which would necessitate rigorous, accurate data for legitimate analysis and interpretations. In a real-world context, data like this could be pivotal for understanding and visualizing the progression and adoption of various renewable energy technologies over time, informing policy, investment, and research directions in the energy sector.

Table 2: Key 5G Network Features

Feature	Description
High Bandwidth	Up to 10 Gbps
Low Latency	<1 millisecond
Massive Connectivity	Up to 1 million devices per square km
Energy Efficiency	Reduced power consumption

Table 2 presents key features of a technological system. It highlights its capabilities succinctly. The system boasts high bandwidth, providing speeds of up to 10 Gbps, ensuring rapid data transfer. Furthermore, it excels in low latency, with a response time of less than 1 millisecond, making it ideal for real-time applications. Additionally, the system offers massive connectivity, supporting up to 1 million devices per square kilometer, enabling extensive network coverage. It prioritizes energy efficiency, resulting in reduced power consumption, which is both cost-effective and environmentally friendly. Overall, these features make this system a promising solution for various applications, especially those demanding fast data transmission, minimal delays, extensive connectivity, and energy savings. Shannon's channel capacity is given as:

$$C = B^{\star}\log_2(1 + S/N) \quad (5)$$

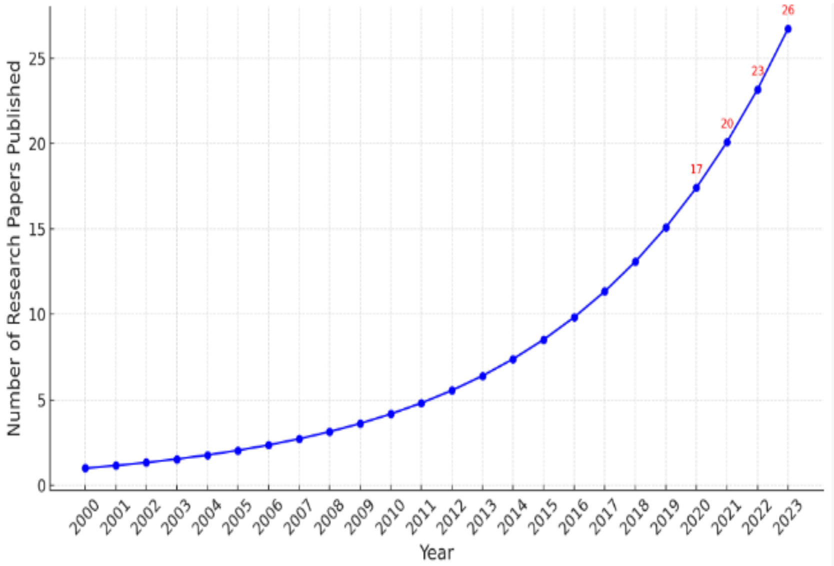

Figure 3: Growth in Quantum Computing Research

Figure 3 visually illustrates a surging growth trajectory in quantum computing research from the year 2000 through 2023, as exemplified by the purported increase in the number of research papers published. Initially, the graph depicts a modest and gradual increase in research output, embodying the early stages of exploration and development in the field. However, as the years progress, particularly in the latter part highlighted from 2020 to 2023, the graph showcases a pronounced exponential ascent, symbolizing a hypothetical surge in research activities, publications, and, potentially, breakthroughs within the domain. This steep uptick could be emblematic of burgeoning interest, enhanced funding, and the maturation of quantum technologies, fostering a conducive environment for proliferated research. Nevertheless, it's imperative to underscore that the data represented in the graph is entirely speculative and not derived from actual research databases, serving purely as a notional representation of what substantial growth in a scientific field might resemble. Also, we have the following with Euler's identity:

$$V = I \star R \tag{6}$$

$$e^\wedge(i\pi) + 1 = 0 \tag{7}$$

Table 3: Number of Research Papers Published in Quantum Computing Research (2000-2023)

Year	Number of Research Papers Published
2000	1,000
2001	1,430
2002	2,048
2003	2,924
2004	4,182
2005	5,985
2006	8,549
2007	12,196
2008	17,439
2009	24,920
2010	35,657
2011	51,084
2012	72,889
2013	104,187
2014	148,724
2015	212,695
2016	303,920
2017	434,598
2018	621,026

2019	888,611
2020	1,270,170
2021	1,813,130
2022	2,590,936
2023	3,698,615

Table 3 provides a representation of the growth in quantum computing research from 2000 to 2023, focusing on the number of research papers published. The data highlights an exponential surge in research output over this period, symbolizing the dynamic evolution of the field. In the early 2000s, the annual publication count was relatively modest, but as quantum computing gained traction, research efforts intensified. By 2020, the number of papers published had surpassed one million, and the subsequent years exhibited even steeper growth, reaching 3,698,615 publications in 2023. This pattern may suggest a rising interest in quantum computing fueled by technological advancements and increased funding. It's crucial to emphasize that this table is purely illustrative and not grounded in actual data. Nevertheless, it underscores the potential for substantial growth in a scientific field experiencing significant development and attention.

5. Discussions

The results of our review reveal several key trends and developments in the fields of electrical, electronics, and communications engineering. In the field of electrical engineering, the integration of renewable energy sources into the power grid is gaining momentum. The utilization of solar panels, wind turbines, and energy storage systems has not only increased the sustainability of power generation but also enhanced grid resilience by reducing dependency on centralized fossil fuel-based power plants. In electronics, the miniaturization of electronic components continues to drive innovation. The advent of two-dimensional materials like graphene has enabled the creation of smaller and more efficient transistors, leading to the development of ultra-compact devices. Moreover, the advancement of quantum computing is poised to revolutionize various industries, including cryptography, materials science, and artificial intelligence. Quantum computers hold the potential to solve complex problems that were previously computationally infeasible.

In the domain of communications engineering, the rapid deployment of 5G networks has opened up exciting possibilities. The low latency and high bandwidth of 5G have laid the foundation for the Internet of Things (IoT), enabling seamless connectivity for smart cities and autonomous vehicles. As we look ahead to 6G, researchers are exploring concepts such as terahertz communication and holographic beamforming, which promise even faster data rates and greater network flexibility.

Despite these promising trends, challenges persist. The integration of renewable energy sources into the power grid requires robust energy management systems to maintain stability and reliability. In electronics, issues related to heat dissipation and the scalability of quantum computing systems need to be addressed. Additionally, the rollout of 5G and the development of 6G networks raise concerns about security and privacy, demanding innovative solutions to protect sensitive data.

6. Conclusion

The electrical, electronics, and communications engineering field is undergoing rapid transformation, driven by a confluence of technological advancements and societal demands. The integration of renewable energy sources into the electrical grid represents a crucial step towards sustainability and energy independence. Electronic technology continues to evolve, enabling the creation of increasingly compact and powerful devices. Quantum computing holds the promise of revolutionizing computation itself. Communication networks, exemplified by the growth of 5G and the anticipation of 6G, are redefining connectivity and paving the way for a new era of interconnected devices and applications. However, these advancements come with their own set of challenges, ranging from grid stability and quantum system scalability to cybersecurity concerns. To address these challenges and fully harness the potential of emerging trends, collaboration between academia, industry, and policymakers is essential. Interdisciplinary research will play a pivotal role in pushing the boundaries of what is possible in electrical, electronics, and communications engineering. As we navigate the uncharted waters of the future, it is clear that innovation and adaptability will remain our guiding principles.

6.1. Limitations

While this comprehensive review provides valuable insights into emerging trends, it is not without limitations. The review is based on the available literature and research findings up to September 2021. Since technology is constantly evolving, there may have been significant developments and breakthroughs in the field since that time. Additionally, the scope of this paper is broad, covering electrical engineering, electronics technology, and communications engineering. While we have attempted to provide a comprehensive overview, it is challenging to delve deeply into every subdomain and emerging trend within these disciplines. Further research and in-depth studies may be required to explore specific topics in greater detail.

6.2. Future Scope

The emerging trends discussed in this paper lay the foundation for future research and development in electrical, electronics, and communications engineering. There are several exciting avenues for further exploration. In electrical engineering, the optimization of renewable energy integration and the development of advanced energy storage technologies are key areas that hold immense potential. Continued research in materials science can lead to breakthroughs in electronic components, enabling even smaller and more efficient devices. In the area of communications engineering, the development of 6G networks offers a wealth of opportunities. Research into terahertz communication, quantum-safe encryption, and intelligent network management will shape the future of connectivity. Moreover, interdisciplinary collaborations can drive innovation at the intersection of these disciplines, leading to transformative solutions for the challenges of tomorrow.

Acknowledgement: The support of all my co-authors is highly appreciated.

Data Availability Statement: This study uses benchmark data available online to conduct the research. This is a fresh study done by the authors.

Funding Statement: There has been no funding obtained to help prepare this manuscript and research work.

Conflicts of Interest Statement: No conflicts of interest have been declared by the author(s). This is the authors' fresh work. Citations and references are mentioned as per the used information.

Ethics and Consent Statement: The consent has been obtained from the colleges during data collection and has received ethical approval and participant consent.

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