GENERATIVE AI FOR THE POWER SECTOR: APPLICABILITY, SAFETY, AND TRUSTWORTHINESS

Khaled Alshehri and Moamar Sayed-Mouchaweh
King Abdullah Petroleum Studies and Research Center (KAPSARC), PO Box 88550, Riyadh, 11672, Saudi Arabia
(khaled.shehri@kapsarc.org;moamar.sayedmouchaweh@kapsarc.org)

Overview

Over the last few years, Generative AI (GenAI) has garnered significant interest for its applications in energy, economics, and many other fields. While artificial intelligence in the energy sector is not new, the recent rise of GenAI—especially following the release of ChatGPT by OpenAI in 2022—has raised numerous open-ended questions. In this study, we take a holistic approach to explore the intersection of GenAI and the power sector.

Broadly, we clarify the distinctions between classical machine learning methods and GenAI (Böcking, et al. 2024), highlighting key challenges such as safety and trustworthiness within the context of the power sector (Choi, et al. 2024). Specifically, we provide historical perspective and an overview of the applications of GenAI across the power sector value chain, including generation, transmission, distribution, and demand-side management (IRENA 2019). Additionally, we examine key enabling horizontal applications such as knowledge management, cybersecurity, and predictive maintenance.

We also discuss prominent issues and ongoing debates surrounding this transformative technology, with a particular focus on trustworthiness and safety in the power sector. Finally, we explore policy implications and offer practical recommendations for deploying GenAI in real-world scenarios, along with actionable insights for electrical and software engineers. This study serves as a foundational step toward analyzing and quantifying the potentially transformative impact of GenAI on power systems operations and economics.

Methods

We employ a comprehensive and interdisciplinary approach in our study, reflecting the rapid advancements of this fast-moving technology. Our analysis begins with a comparative exploration of traditional machine learning methods and GenAI, highlighting their respective strengths and limitations in power system operations and economics. To examine the transformative potential of GenAI, we review existing and emerging applications across generation, transmission, distribution, and demand-side management.

To address safety and trustworthiness, we conduct in-depth qualitative analyses of key risk factors, exploring frameworks for mitigating biases, ensuring data security, and enhancing system robustness. Additionally, we consider the implications of GenAI from the perspective of electrical engineers, particularly in relation to its growing energy demand. Practical tips and key software engineering principles are synthesized to support the efficient deployment of GenAI products and services across the power sector (Bengio, et al. 2024).

Finally, we undertake a policy analysis to evaluate current governance frameworks and offer recommendations for regulatory adaptation, ensuring the responsible deployment of GenAI as it continues to evolve and shape the energy sector.

Results

Our findings demonstrate that various GenAI methods hold significant promise across a range of applications in the power sector. These applications include predictive maintenance, dynamic line monitoring, load disaggregation, knowledge management systems, and cybersecurity, each offering unique opportunities to enhance operational efficiency, improve system reliability, and support informed decision-making within power systems and enabling innovate retail market designs.

However, our analysis reveals that the success of GenAI deployment depends on several critical factors. These include access to high-quality data and computational resources, the complexity of integration with existing infrastructure, alignment with power systems engineering challenges, and the economic viability of implementation.

While the potential of GenAI is substantial, challenges related to its trustworthiness, safety, and compliance with governance frameworks remain pivotal for real-world depoloyment. These findings underscore the importance of prioritizing use cases that ensure GenAI solutions are not only impactful and feasible but also safe and aligned with sector-specific requirements. To navigate these complexities, we provide practical recommendations and policy insights tailored for electrical engineers, AI practitioners, market designers, and regulators.

Conclusions

This study highlights the complexity of applying GenAI to the power sector, a truly interdisciplinary challenge. Navigating its potential, economic value, trustworthiness, safety, and regulatory frameworks requires comprehensive analysis and ongoing dialogue. It serves as a steppingstone toward creating a holistic roadmap for addressing GenAI's role in the power sector as a cyber-physical-social system, tailored to the needs of various stakeholders and practitioners.

References

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