



TRADE & INDUSTRIAL POLICY STRATEGIES

INDUSTRY STUDY

TECHNOLOGICAL CHANGE IN

THE ELECTRICAL EQUIPMENT INDUSTRY

January 2025

TIPS industry studies aim to provide a comprehensive overview of key trends in leading industries in South Africa. For each industry covered, working papers will be published on basic economic trends, including value added, employment, investment and market structure; trade by major product and country; impact on the environment as well as threats and opportunities arising from the climate crisis; and the implications of emerging technologies. The studies aim to provide background for policymakers and researchers, and to strengthen our understanding of current challenges and opportunities in each industry as a basis for a more strategic response.

This study assesses technological advancements in the electrical equipment industry and their presence and applications in South Africa.

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INTRODUCTION

Enabled by advancements in digitalisation and connectivity, technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), digital twins, virtual reality (VR), augmented reality (AR), and additive manufacturing are transforming industrial processes. Among other things, these technologies enhance efficiency and sustainability by enabling remote monitoring and control, automation, predictive maintenance, and streamlined manufacturing. This study assesses technological advancements in the electrical equipment industry and their presence and applications in South Africa. It is the second in a series of studies on the South African electrical equipment industry, with the first study, [Industry Study: Electrical Equipment](#), providing an overview of the industry (Robb, 2023).

This study begins by describing emerging technologies enabled by advancements in digitalisation and the positive impacts associated with their adoption. The next section highlights the factors that are driving the adoption of emerging technologies, and outlines the challenges hindering its uptake. The fourth section examines technological changes in the electrical equipment industry, and highlights key entities involved in these advancements. The fifth section assesses trends in South Africa, including the integration of emerging technologies into electrical equipment, the role of institutions in supporting innovation, and the barriers preventing widespread adoption. The sixth section concludes the study.

1. EMERGING TECHNOLOGIES

The emerging technologies assessed in this study include IoT, AI, digital twins, AR, VR, and additive manufacturing. By enabling remote monitoring and control, automation, predictive maintenance, and optimisation, these technologies are key to managing global trends that require enhanced efficiency and sustainability (Siemens, 2020; Cunningham, 2023; Siemens, 2023). The proliferation of emerging technologies have been driven by advancements in digitalisation. In industrial settings, these technologies integrate specialised software, hardware, and connectivity to collect, process, and analyse data to facilitate decision-making and optimise processes. Table 1 provides a brief description of emerging technologies and outlines positive impacts associated with their adoption.

Table 1: Emerging technologies and their impact

| TECHNOLOGY | DESCRIPTION | IMPACT |
|-------------------------|--|---|
| Internet of Things | IoT refers to a network of interconnected devices that collect, analyse, and transmit data through sensors, communication devices, and computers. The integration of IoT facilitates remote monitoring and control of assets and processes. The Industrial Internet of Things (IIoT) is used to monitor, control, and optimise equipment and processes in industrial contexts. The technology can monitor, for example, the temperature of a machine, or the rotations of a motor, to determine whether they are performing optimally or if maintenance is required. | Enhances operational and cost efficiency by enabling the remote monitoring and control of processes and predictive maintenance. |
| Artificial Intelligence | Industrial AI is a technology that combines computer science and data from equipment and processes to mimic human | Enhances operational and cost efficiency, advances innovation, improves quality. |

| TECHNOLOGY | DESCRIPTION | IMPACT |
|--------------------------------------|---|--|
| | intelligence in learning, decision-making, and problem-solving. Industrial applications of AI include generating advanced designs, and the automation of tasks. | |
| Digital Twin | A digital twin is a virtual representation of a physical object or process. It is generated using data collected from sensors connected to the physical world. In industrial settings, it can be used to model entire plants or individual components. It can also capture interactions within electronic, electrical, and mechanical systems. | Enables faster simulations, and provides safe environments for testing and training. |
| Additive manufacturing (3D printing) | Additive manufacturing is a process of producing objects by adding material layer by layer, based on a digital design. Unlike traditional subtractive methods, which involve cutting or drilling away material, additive manufacturing builds objects by adding material. | Reduces wastage and results in fewer carbon emissions as products can be produced locally, reducing transportation costs and emissions. |
| Augmented Reality | AR is a partially immersive technology that layers digital content onto the real world. AR applications range from text notifications to fully interactive, step-by-step instructions. In industrial contexts, technicians performing maintenance on machinery and equipment could, for example, use AR glasses to view procedures or diagrams overlaid on physical equipment. | Enhances efficiency by enabling faster and more accurate repairs. Eliminates the need to refer to printed manuals, which can be outdated and cumbersome. |
| Virtual Reality | VR technology creates a completely immersive, artificial environment in which users can interact with digital elements as though they are real. VR is typically experienced through specialised headsets and controllers, which track the user's movements and provide sensory feedback. For industrial purposes, VR is used to replicate physical objects and facilities for testing and training. | Enhances training, as workers can practice high-risk tasks safely. |

Source: Adapted from Zhukovskiy and Koteleva, 2019; Siemens, 2020; Naseer et al., 2021; Cunningham, 2023; Siemens, 2023; and The Princeton Review, no date.

2. TECHNOLOGICAL CHANGE: DRIVERS AND BARRIERS

In addition to advancements in connectivity, efficiency and sustainability objectives are key drivers of the adoption of emerging technologies in electrical equipment. Considering their advanced nature, however, implementation is not without challenges. This section examines the forces driving technological change, and outlines a selection of barriers that prevent seamless and widespread adoption.

Businesses and utilities are increasingly turning to digital solutions, that leverage data analytics and remote monitoring and control, to reduce downtime and optimise the performance of assets. These technologies are also seen as contributing to reducing costs and carbon emissions, and streamlining design and production (Siemens, 2023).

Efficient and sustainable electrification are also driving technological changes in electrical equipment. Rapid population growth – particularly in developing countries – has fuelled the need for efficient, and sustainable infrastructure solutions (Siemens, 2023). Simultaneously, the need to upgrade existing electricity infrastructure in many regions has intensified, as traditional systems often fail to meet modern efficiency and environmental standards. Similarly, global climate change commitments have led to a rise in the installation of renewable energy technology, which relies on advanced components for optimal integration into existing energy systems. In addition, increased consumer awareness of environmental impacts and growing demand for smarter, greener technologies have prompted businesses and governments to respond by providing technologically advanced products and services. These economic, demographic, environmental, and cultural factors are accelerating the technological transition (Siemens, 2023).

While emerging technologies can enhance efficiency and sustainability, they can be difficult to adopt. Adopting emerging technologies can be costly, as they require investment in skills, infrastructure, and a shift in processes. Additionally, as a result of their digitalised and connected nature, the adoption of emerging technologies could leave systems vulnerable to cyberattacks (Jagdale, 2023). Furthermore, the automation capabilities offered by new and emerging technologies threaten jobs, particularly those that entail repetitive tasks (Sutherland, 2020). Moreover, long exposure to immersive technologies can lead to health complications and workplace hazards (Adamska, 2023).

Despite the problems associated with emerging technologies, their positive contributions are undeniable. The application of emerging technologies in the electrical equipment industry, their benefits, and the entities that are involved in implementation are examined in the next section.

3. TECHNOLOGICAL CHANGES IN THE ELECTRICAL EQUIPMENT INDUSTRY

This section assesses emerging technologies in the electrical equipment industry in two ways. In the first instance, it examines how some of these technologies have been applied to a selection of electrical equipment. This includes IoT and AI for electric motors, digital twins for electric transformers, augmented reality for wiring, and additive manufacturing for lighting. In the second instance, it assesses the application of emerging technologies in electrical utilities. By no means does this section constitute an exhaustive examination, as different technologies can be applied to different products.

3.1. IoT for electric motors

Electric motors equipped with intelligent sensors and network connectivity can transmit real-time data about their operations. This allows for constant monitoring of performance, condition, and efficiency, ensuring that systems operate optimally (DeAngeli Prodotti, 2024). The application of IoT to electric motors is similar to its application in capital equipment, like pumps (Mthembu, 2024).

In electric motors, IoT-enabled sensors gather and analyse data related to motor vibration, speed, and temperature to identify potential failures or malfunctions before they occur. This assists in minimising downtime, extending lifespan, and reducing repair costs (DeAngeli Prodotti, 2024). Moreover, IoT technology facilitates remote control of electric motors, enabling remote adjustments to operational

parameters. This is useful in situations where physical access to the motor is difficult or hazardous. IoT integration also promotes energy efficiency by allowing for the optimisation of motor performance through ongoing data analysis (DeAngeli Prodotti, 2024).

An example of IoT integration in electric motors is a solution from Siemens that equips low-voltage motors with a sensor box to monitor key operational and condition parameters. These parameters are transmitted via Wi-Fi to the cloud, where they are processed and analysed using an application on the Siemens IoT platform. The application provides users with detailed motor data and insights, including recommendations for preventive maintenance (Siemens, 2017). In 2018, Zest WEG (now WEG) launched a similar solution, which is covered in the next section.

3.2. AI for the design of electric motors

In addition to their automation and predictive maintenance capabilities, AI algorithms can analyse extensive datasets of electrical components and design rules, and produce optimised designs more efficiently than manual methods (Patterson, no date). AI also enables virtual prototyping, where engineers can simulate electrical systems and test designs in a digital environment, eliminating the need for costly physical prototypes, which speeds up the development of optimal designs (Patterson, no date).

Mitsubishi Electric and Toshiba Mitsubishi-Electric Industrial Systems Corporation (TMEIC) have developed an AI-powered motor design technology for electric motors that reduces design times from three days to three hours. The AI system streamlines the design process by suggesting optimal specifications based on historical data, allowing engineers to make quick adjustments, through an interactive process, until desired outcomes are achieved. The system also helps standardise processes and transfer design skills (Drives & Controls, 2022). This use of generative AI is being explored in parts of the automotive industry, such as wheel design (Sergeev, 2023; Lee, 2024).

3.3. Digital twin technology for electrical transformers

Digital twins model individual power assets as well as electrical networks, and serve various purposes (Thomas, 2023). As diagnostic tools, they help identify the root causes of issues, and improve future mitigation strategies. Digital twins also serve as training and maintenance tools by simulating operations before they are performed on-site. In predictive maintenance, the technology can compare expected and actual asset behaviour to predict when maintenance is needed (Thomas, 2023).

One example of digital twin technology in electrical equipment is its use in the management of power transformers. Siemens digital twin technology, for example, creates a virtual model of transformers, using real-time data such as winding currents, cooling status, and ambient temperatures, along with a thermo-hydraulic calculation model. These models can simulate temperature behaviour, overload capacities, and insulation ageing, with operators being able to access the information at all times. It also provides visualisation tools to support decision-making when evaluating equipment (Transformer Technology Comm, no date). Digital twin technology also has its applications in the capital equipment industry, as evidenced by its application in cranes (Siemens, no date).

3.4. AR for electrical wiring

In the electrical equipment industry, AR enables technicians to access critical information in real time, directly in their field of view, making workflows more efficient and reducing the potential for human error (Zhukovskiy and Koteleva, 2019). AR systems can guide workers step-by-step, displaying

instructions directly in their line of sight, via AR glasses or another device. These systems can also overlay historical data, defect insights, and instructions onto electrical equipment, and provide step-by-step guidance on resolving issues (Zhukovskiy and Koteleva, 2019; Ibarra, 2021)

In terms of its applications in electrical equipment, Boeing uses AR technology for the wiring of its aircraft (Ibarra, 2021). Using AR glasses, technicians view detailed, interactive 3D models of the aircraft and its components overlaid on the real-world assembly line. This allows them to follow precise instructions, view wiring schematics, and ensure that parts are installed correctly. According to reports, the adoption of AR has assisted Boeing reduce errors, improve efficiency, and streamline training (Ibarra, 2021). AR is applied in a similar manner in the healthcare industry. Among other things, during medical procedures it allows surgeons to view patients' vital organs without needing to consult multiple devices, thereby reducing data interpretation and, hence, procedural errors (Figent, no date).

3.5. Additive manufacturing for lamps, lighting and coils

Additive manufacturing is revolutionising efficiency and sustainability in the processing of various materials, including plastics, metals, and ceramics (Diale, 2024). In the manufacture of lamps and lighting, 3D printed products use fewer materials, can incorporate recyclable products, and results in fewer carbon emissions as products can be produced locally, reducing transportation emissions (Bolt, 2024). There are also personal benefits, as fittings and fixtures can be customised depending on preferences. Among the companies involved in additively manufacturing lamps and lighting is Signify, formerly Philips Lighting. Not only does the company produce energy-efficient luminaires, its products are customisable, and its printed parts use sustainable materials (Signify, no date).

Coils/windings have also been enhanced through 3D printing. Research has indicated that copper-alloy windings that were manufactured using 3D printing showed a 20% improvement in continuous operational output due to reduced AC losses (Naseer et al., 2021). In addition to the problems inherent with digitalising and automating industrial processes (Section 2), additive manufacturing for electrical equipment has some unique constraints. These include the maximum size of print beds, and insufficient research on the electromagnetic properties of printed parts. Despite this, however, major corporations, such as General Electric, Boeing, and Rolls-Royce use additively manufactured components in their products (Naseer et al., 2021).

3.6. Emerging technologies applied in electrical utilities

As articulated in the previous subsection, integrating emerging technologies into electrical equipment enhances efficiency and sustainability. Given that electrical equipment, like electric motors, transformers, and wiring, generally constitute a component of a larger system, the integration of emerging technology also enhances efficiency and sustainability in electrical networks. As a result, they are increasingly being adopted by electrical utilities.

In addition to aiding in the remote monitoring and control of facilities for proactive maintenance, IoT plays an important role in integrating renewable energy sources – crucial for achieving net zero carbon emissions (Liyakat and Liyakat, 2023). By monitoring production, consumption, and energy storage, IoT can manage energy use and source, allowing for the optimal use of resources (Panton, 2023). AI enhances IoT's capabilities by leveraging machine learning and predictive analytics. AI systems can forecast energy demand, adjust supply, and facilitate energy conservation mechanisms. In addition, AI can manage the variability of renewables alongside the constant demand of the grid, through algorithms that analyse weather patterns and forecast renewable energy supply (Sofio, 2024). VR, in

electrical facilities, supports training, testing, and validation by immersing users in realistic simulations of facilities and systems (Siemens, 2020).

The Dubai Electricity and Water Authority (DEWA) uses advanced technologies to improve utility services and enhance satisfaction for customers and stakeholders (Government of Dubai, 2024). DEWA has integrated AI across power generation, transmission, and distribution to predict changes and respond quickly to evolving demands. Its approach includes using AI to detect and respond to cybersecurity threats, automate substation monitoring with robots, and optimise network design by forecasting load demand and assisting engineers with tailored recommendations. VR and AR tools are used for staff training, improving safety, and streamlining technical operations. The utilities authority also engages with residential customers through an energy conservation programme that provides insights on usage, comparisons with similar homes, and tips to save electricity and water, promoting sustainability and reducing the overall carbon footprint (Government of Dubai, 2024).

The application of emerging technologies described in this subsection is found in various industries, including water and gas utilities.

4. TECHNOLOGICAL TRENDS IN SOUTH AFRICA

The technological advancements in electrical equipment discussed in this study are, indeed, present in South Africa. However, industrial innovation is largely driven by international firms operating within the country. In addition, despite institutional support geared towards advancing innovation, challenges in developing and applying innovative technologies persist. This section of the study delves deeper into these aspects.

4.1. Technological changes in the South African electrical equipment industry

One example of IoT in electrical equipment, in South Africa, is the WEG Motor Scan solution. The electric motor performance monitoring technology, launched in 2018, seeks to assist large industrial operations perform proactive motor maintenance to avoid unplanned downtime. The motor scan allows for the monitoring of information related to radial and axial vibrations, motor temperature, and operating time. The device's sensor enables automatic extraction of operational data from the motor, transmitting it to the cloud. Users can access and analyse the stored data directly on their mobile devices or explore it in greater detail on the WEG IoT platform, where the data undergoes automated processing and analysis. The device also supports the configuration of maintenance alerts, prompting users to conduct routine checks after predefined operating intervals (Muller, 2018).

In terms of digital twins, Hitachi Energy has a digital twin solution for high-voltage direct current systems and power quality applications. The solution consolidates asset information analytics, and operational data into a user-friendly, customisable dashboard. The platform also features interactive 3D visualisations of assets and offers access to related plant and equipment details, including operational guidelines, engineering documentation, maintenance procedures, and safety training resources (South African Instrumentation and Control, 2022).

With AR, BEKA Schröder, a Belgian manufacturer of street lights and other luminaires, with operations in Gauteng, launched a "world first" digital application that allows users to interact with their products remotely. The app enables users to visualise BEKA Schröder's products and poles in real-world environments, both indoors and outdoors, using augmented reality. Users can toggle product lighting to compare optics and photometry. The app also allows zooming in on product features to highlight

unique details and provides an option to capture and digitally share snapshots of the augmented reality scene (Engineering News, 2018).

An application of IoT in utilities is seen in the collaboration between Siemens, Lamo Solar, and the German Agency for International Cooperation (GIZ), in electrifying the Upper Blinkwater village of the Eastern Cape. The microgrid project comprises solar PV, a diesel backup, battery energy storage, and the Siemens SICAM Microgrid Controller. The SICAM Controller controls the energy source and ensures the efficient use of electricity. With the system, households in the village have at least enough power for a cell phone charger, a kettle, and a TV and satellite dish (Panton, 2023).

Another IoT trend in South African utilities is household smart electricity meters. These systems are enhancing accuracy in the billing process, and providing information to consumers to empower their decision-making (Macrocomm, 2024). The installation of these components is receiving government support, as Eskom, in 2023, announced a R16 billion plan to put a smart meter in every household (Zeeman, 2023). In a partnership that seeks to address South Africa's energy gap, Vodacom is among the entities assisting in Eskom's smart metering drive (Vodacom, 2024).

For household solar installations, Plentify's SolarBot is an energy management solution that combines IoT with AI to optimise the use of solar panels and batteries in homes. It analyses loadshedding schedules, weather patterns, and customer demand to make decisions. By combining weather data with real-time system performance, SolarBot ensures that solar energy is used efficiently, minimising waste when there is insufficient demand. It can also work in conjunction with Plentify's HotBot to optimise geyser performance and direct excess energy to other appliances. Through a connected platform, users can monitor and control their energy use, track savings, and reduce reliance on the grid (Arnoldi, 2024).

4.2. Institutional support

South Africa has a variety of institutions that support technological advancements in the electrical equipment industry. Given South Africa's decarbonisation commitments, however, institutional support for innovation in electrical equipment is predominantly geared towards sustainable infrastructure development.

In terms of stimulating the adoption of emerging technologies in electrical equipment, the 12L Income Tax Allowance allows qualifying taxpayers to claim a deduction for energy efficiency savings resulting from activities adopted in operations (SARS, 2024). Likewise, the carbon tax seeks to incentivise decarbonisation by levying a charge on carbon emissions, encouraging the adoption of efficient and sustainable solutions in energy systems. These mechanisms indirectly support the adoption of new technology in electrical equipment and systems.

In terms of government finance, the Machinery, Equipment and Electronics Strategic Business Unit (SBU) of the Industrial Development Corporation (IDC) supports the manufacturing of machinery and capital equipment, including in electricity generation, transmission and distribution, with innovations in electronics and robotics. Assistance includes providing finance for capacity expansion, increasing competitiveness, and enhancing market access (IDC, 2022b). Likewise, the Energy SBU provides funding for operations geared towards the development of mini grids and microgrids (IDC, 2022a).

In terms of research and development, the Living Energy Lab is a technology research platform developed by the Council for Scientific and Industrial Research (CSIR) that is used to explore approaches to the energy transition (CSIR, no date). The capabilities of the Lab include a smart grid

laboratory that enables real-time digital simulations, as well as microgrid technologies that incorporate AI, and AR (CSIR, no date).

Educational institutions also play a key role in building capacity. In addition to offering programmes that equip students with the skills required for the digital world, South African universities have also launched initiatives that seek to advance innovation. For example, the University of Pretoria (UP) has designed a digital twin city for Hatfield. The Hatfield Digital Twin City (HDTC) provides real-time virtual models of urban structures and resource flows, using data from sensors and communication technologies. Its aim is to enhance city services, infrastructure, environments, and social, industrial, and health outcomes. In terms of electricity, the HDTC seeks to establish a comprehensive smart grid to monitor electricity usage across the precinct, helping the municipality to allocate electricity based on energy requirements (UP, 2021).

There are also instances in which government entities have collaborated with educational institutions to enhance innovation in the industry. For example, the Smart Grid Research Centre, located at the University of KwaZulu-Natal (UKZN), is part of a collaboration between UKZN and Eskom that plays a key role in developing South Africa's smart grid. The facility is dedicated to training and research in smart technologies, as well as the integration of renewable energy sources into the grid through modelling, simulation, and real-time analysis (UKZN, no date).

4.3. Barriers hindering the adoption of new and emerging technologies in South Africa

Despite the existence of various mechanisms supporting the uptake and advancement of emerging technologies, a multitude of barriers prevent widespread adoption in South Africa. While universities have included advanced technological content in their offerings, South Africa's education system has fallen short of sufficiently preparing the workforce for technological change. In addition, poor infrastructure and weak governance hinder advanced digitalisation. In terms of the labour market, automation technologies pose a threat to jobs that entail repetitive tasks, which could worsen the triple challenge of poverty, inequality, and unemployment (Sutherland, 2020).

5. CONCLUSION

The electrical equipment industry is, evidently, undergoing a notable digital transformation, driven by emerging technologies such as IoT, AI, digital twins, AR and VR, and additive manufacturing. By enabling remote monitoring and control, automation, waste reduction, and further innovation, these advancements enhance efficiency and sustainability across various facets of the economy.

In South Africa, the integration of these technologies in electrical equipment has gained momentum, and is expected to grow over the medium term. However, innovation is driven, largely, by foreign entities, and barriers to widespread adoption persist, requiring greater support for innovation and scaling. While various entities are involved in fostering progress, greater investment and collaboration is crucial for South Africa to advance the development and adoption of new and emerging technology within the electrical equipment industry.

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