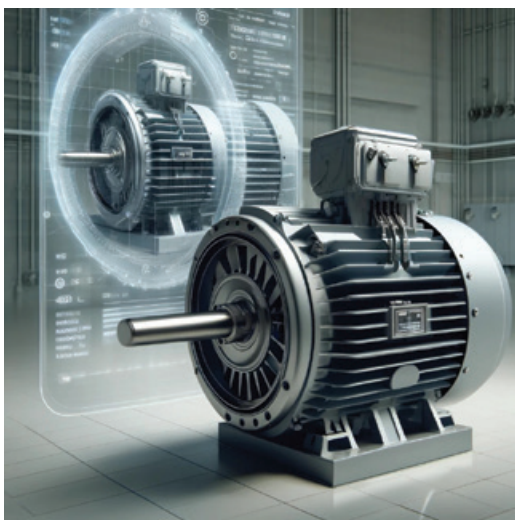


# Next-generation maintenance: harnessing the Internet of Things, Artificial Intelligence, robotics, and metaverse technologies

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**Figure 1.** "Digital Twin Mastery" – Harnessing the power of a motor's digital twin for precision maintenance.

## THE DAWN OF MAINTENANCE 4.0

The fourth industrial revolution, or Industry 4.0, represents a pivotal transformation in the industrial landscape, significantly impacting maintenance practices—a critical aspect of industrial operations. It is distinguished by the integration of digital technologies, such as the Internet of Things (IoT), Artificial Intelligence (AI), and Big Data analytics, directly into the fabric of industrial processes. These technologies are redefining how machinery and systems communicate, operate, and are maintained.

Maintenance, traditionally reactive and often seen as a necessary but costly part of operations, is evolving under Industry 4.0. The approach is shifting from periodic and preventive maintenance to strategies that are more predictive and efficient. This shift is driven by the ability to collect and analyse vast amounts of operational data in real time. Industries are now able to anticipate machine failures before they occur, plan maintenance activities more effectively, and reduce unplanned downtime, thus enhancing operational reliability and efficiency. By implementing sensor-based monitoring systems, plants can predict and address potential equipment failures before they occur, leading to a 30% reduction in downtime and a 20% reduction in maintenance costs. These real-world figures underscore and confirm the tangible benefits of evolving maintenance practices under Industry 4.0.

The core of Industry 4.0's impact on maintenance is its ability to automate and optimize processes that were previously manual and intuition-based. Through the connectivity offered by IoT, machines are not only capable of self-monitoring but also of communicating their state and needs instantaneously. This connectivity ensures maintenance can be scheduled at optimal times, based on actual wear and performance, rather than on predetermined intervals.

As these technologies become more integrated into industrial systems, the role of maintenance is being reimagined. It is no longer just about preventing failure but also about leveraging technology to make maintenance a cornerstone of operational intelligence and efficiency. This paradigm shift will enhance the longevity and performance of industrial assets and transform maintenance into a strategic component of the enterprise, crucial for driving innovation and maintaining competitive advantage in a rapidly evolving industrial environment.

## TRANSITION TO INDUSTRY 4.0: A TECHNOLOGICAL EVOLUTION

The transition to Industry 4.0 represents a profound shift in manufacturing and industrial sectors, driven by the deep integration of digital technologies into core operational frameworks. This evolution goes beyond the adoption of advanced tools; it is reshaping the very nature of how factories and plants operate, facilitating a new level of connectivity and intelligence.

IoT is at the heart of Industry 4.0, as it enables an unprecedented level of communication between machines. IoT devices are embedded throughout the industrial landscape, collecting and transmitting data from myriad points along the production line. This constant flow of information allows real-time monitoring and analysis of operational conditions, leading to more informed decision-making and rapid response capabilities.

Thanks to IoT technology, machines not only collect vast arrays of data; they also communicate seamlessly among themselves and with central management systems. This network of connected devices provides a continuous stream of real-time data, transforming maintenance strategies from reactive to proactive. The integration of AI further leverages these data, employing advanced analytics to predict potential failures and optimize operations, thus significantly enhancing operational efficiency and reducing downtime. These technologies process vast amounts of data to uncover patterns and insights that were previously inaccessible. By analysing trends across entire systems, AI can optimize maintenance schedules and operational procedures, ensuring that machines operate at peak efficiency.