How Industry 4.0 Digital Technologies Optimise Energy Use in Plants

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Abstract

Since the chemical industry touches almost all industries in one way or another, the use of Industry 4.0 digital technologies is imperative to ensure efficient energy use across these facilities. This article offers a broad overview of key measures used by chemical manufacturers.

Introduction

The Fourth Industrial Revolution – also known as Industry 4.0 – refers to the introduction of digital technologies into industry. One of the main features of smart manufacturing is its ability to collect, process and analyse data, communicate with other systems and even take appropriate actions. In this landscape, energy efficiency is a crucial strategy for improving industry's economic performance while reducing industrial pollution. Given the severe consequences of climate change and the role of various industries, including the chemical industry, in increasing global CO_2 emissions, energy efficiency is considered an important mitigation measure.

Due to fluctuating feedstock supplies, increasingly stringent environmental regulations, and complex regulatory processes, modern chemical factories face mounting operational challenges. This includes growing pressure on the chemical industry to reduce resource consumption and emissions without compromising profitability. By leveraging technologies that collect and analyse data, digitalisation can enhance energy efficiency and drive real-world improvements in energy use.

Vijay Kumar Srivastava, Chief of Operations and Whole Time Director, Jubilant Ingrevia Limited, has been instrumental in driving operational excellence and achieving significant business results. With over 23 years of extensive experience in various industries, including petrochemicals, agrochemicals, and polymers, he has a proven track record of enhancing business practices, increasing productivity, and fostering innovation.

Impact and Imprint of the Global Chemical Industry

The importance of the chemical industry within the global manufacturing chain cannot be overstated. Almost every manufactured item has some input from the chemical industry, in one way or another. Industry 4.0 integrates a range of advanced digital and physical technologies to strengthen the physical-digital-physical connection, thereby transforming the chemical industry by streamlining operations and promoting strategic growth. Advanced technologies relevant to the chemicals industry (the Internet of Things, additive manufacturing, advanced materials, advanced analytics, AI and robotics) have reached a cost-performance level that enables widespread adoption.

Embedding Energy Conservation Mechanisms in Industry Procedures

Since these technologies are highly advanced, they can be integrated into the core conversion or marketing processes of chemical firms, digitally transform their operations, and support smart supply chains and factories, as well as new business models. For instance, companies such as Jubilant Ingrevia have deployed technologies that promote the Fourth Industrial Revolution (4IR). In 2024, the firm's Bharuch manufacturing plant was recognised as a WEF (World Economic Forum) Lighthouse Factory after implementing more than 30 4IR use cases, making it the only Indian company to earn the distinction in this category.

The company is equally committed to conserving energy across its diverse operations. The main focus

areas for energy conservation include improving energy efficiency, recovering waste heat, optimising processes and using alternative renewable energy sources. To elaborate, improving insulation enhances boiler efficiency by boosting combustion efficiency and reducing line losses. Accordingly, some facilities are adopting ISO 50001:2018 compliant energy management systems. Additionally, smart sensors help monitor the power consumption of critical equipment and trigger corrective action, while implementing advanced process control reduces energy use in chemical operations. Vibration sensors are also installed on critical equipment to prevent breakdowns and improve plant energy productivity.

Optimising Steam Consumption and Other Processes

In some plants, steam consumption is reduced through heat recovery, reflux preheating and feed temperature optimisation, utilising process heat integration. Identifying and rectifying faulty steam traps reduces flash steam losses and minimises residual steam in MEE (Multiple Effect Evaporator) systems. Effective utilisation of flash steam in various processes also helps reduce demand for fresh steam. Optimising the reflux ratio in distillation columns through AI-driven data analytics also reduces steam consumption. Likewise, improved chiller efficiency minimises process losses, while replacing steam ejectors with dry vacuum pumps reduces steam consumption and improves process efficiency. Moreover, using fuel additives delivers fuel savings in incinerators and improves combustion performance.

Additional Measures to Strengthen Climate Strategies

In addition to the above measures, chemical companies are strengthening their climate strategies by embedding climate considerations across responsible sourcing and supplier engagement programmes. At the same time, investments in renewable energy, low-carbon technologies, energy efficiency and process innovation offer further opportunities to reduce emissions, improve operational efficiency, enhance resilience and boost long-term competitiveness.

Digital transformation is also reshaping how chemical companies innovate, operate and manufacture. As a result, companies are embedding AI and GenAI solutions across R&D, manufacturing, the supply chain and other verticals to accelerate decision-making and improve efficiency. Similarly, smart control rooms, digital twins and predictive analytics are enabling smarter operations. In this context, digital twin technology is driving the digital transformation of the chemical industry by enabling real-time monitoring, process optimisation and predictive maintenance. Digital twins also help prepare AI-based models that support service teams by evaluating operating scenarios to identify opportunities for efficiency improvements.

Investments in energy-efficiency technologies are no longer discretionary, as rising energy prices, dependence on fossil fuels, supply chain disruptions and evolving climate-related regulations have increased operating costs, carbon emissions and enterprise risks. Conversely, by improving energy efficiency, optimising processes, adopting renewable energy and investing in low-carbon technologies, chemical companies can reduce energy costs, improve operational efficiency, lower carbon emissions, strengthen regulatory compliance and enhance long-term competitiveness.

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Specific, Scalable and Measurable Benchmarks

Keeping sustainability goals in mind, chemical companies assess environmental performance across energy, emissions, waste and water to ensure that improvements are specific, scalable and measurable across all their processes and sites. In a nutshell, sustainability is tracked through clear targets and measurable performance. Finally, the chemical industry is acutely aware of the gravity of climate change and its overall impact on the planet. In the campaign against climate change, Industry 4.0 digital tools and technologies will continue to play a pivotal role in keeping the chemical industry's carbon footprint in check and also reduce the energy bill by 10 to 15%.

Conclusion

Industry 4.0 technologies are becoming essential for improving energy efficiency in chemical plants. By combining digitalisation, AI, advanced analytics and smart systems with sustainable practices, chemical manufacturers can optimise energy use, reduce emissions, lower costs and strengthen long-term competitiveness.