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When machines start thinking, AI rewrites future of sugar and ethanol plants

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In an exclusive AgroSpectrum interview, Mandar Kulkarni, VP & GM, AI Centre of Excellence, Findability Sciences, and Naina Gupta Bandyopadhyay, VP â?? AI Technologies & AI Delivery, Findability Sciences, examine how data-driven intelligence can tame process variability, anticipate disruptions and unlock higher efficiency, recovery and resource productivity across sugar and ethanol plants.

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Industrial AI is beginning to change the operating logic of India’s sugar and ethanol plants, shifting the focus from monitoring what happened to anticipating what happens next. Its immediate value lies not in replacing automation or operators, but in detecting multivariable patterns that signal process drift, equipment deterioration and emerging production losses before conventional alarms are triggered. For highly interconnected sugar complexes and distilleries, this predictive layer can help stabilise operations before pursuing harder gains in recovery, throughput, energy efficiency and product quality. The same intelligence is also making production planning more dynamic, linking cane availability, feedstock quality, equipment condition and real-time plant performance to operational decisions. Sustainability, meanwhile, is increasingly becoming an operational outcome, with AI capable of identifying trade-offs across steam, power, water, extraction, fermentation and distillation rather than optimising isolated parameters. The trajectory points towards increasingly prescriptive plants, although fully autonomous manufacturing remains distant, with human-in-the-loop systems likely to define the next phase.

How is AI-powered digital transformation reshaping operations across India's sugar and ethanol manufacturing sector?

AI-powered digital transformation is reshaping process industries by changing how plants understand, manage and improve operations. In sectors such as sugar and ethanol, production performance is influenced by continuous variability in raw material quality, operating conditions, utilities and equipment behaviour. Historically, this complexity has been managed through operator experience, laboratory testing, standard operating procedures and conventional automation. Those remain important, but they are no longer sufficient on their own. Industrial AI adds a new decision layer. It continuously interprets process data across the plant, detects subtle shifts in behaviour, identifies process drift and helps operational teams respond before the deviation becomes a measurable loss.

In a sugar complex, for example, cane quality, extraction, clarification, evaporation, crystallization, centrifugation, boiler performance, fermentation and distillation are tightly interconnected. A disturbance in one section can propagate through the rest of the process and affect recovery, throughput, steam balance, product quality and cost. The first real value of AI in such environments is stabilization. Before a plant can optimize throughput, recovery or energy efficiency, it must first reduce avoidable variability and operate more consistently within its best-performing range. That is why digital transformation in manufacturing is no longer just about digitizing reports. It is about moving from "What happened?" to "What is changing, what will be the impact, how do we stabilize it, and how do we optimize beyond that?"

How can Predictive AI help manufacturers improve plant efficiency, minimize downtime, and enhance overall productivity?

Predictive AI improves plant performance by identifying early signals of deterioration or instability that traditional rule-based monitoring may miss.

In most plants, alarms are triggered when an individual parameter crosses a threshold. But in reality, many operational problems develop much earlier, when parameters are still technically within limits, but their relationship with other variables has begun to change. A temperature may look acceptable, a pressure may remain stable, and a flow may appear normal, yet the combined behaviour may indicate an emerging problem. AI is particularly effective in detecting these multivariable patterns. This creates four practical layers of value:

Anomaly detection helps identify unusual plant behaviour.

Prediction estimates likely outcomes such as downtime, quality loss, reduced recovery or rising energy consumption.

Root-cause reasoning helps engineers understand which process interactions are likely driving the issue.

Stabilization supports operators in restoring the process to a reliable and repeatable operating window.

Once that stable baseline is achieved, the next stage is optimization. AI can then recommend better operating ranges or setpoints to improve throughput, efficiency, quality or utility consumption while respecting plant constraints. This sequence is critical. In process industries, chasing optimization without first achieving stabilization often leads to short-lived gains and inconsistent outcomes. The sustainable value of Industrial AI lies in helping plants move from stabilization to optimization, not attempting to skip the first step. For manufacturers, the impact is clear: fewer unexpected disruptions, more stable production, lower downtime, better resource efficiency and a gradual shift from reactive management to predictive and prescriptive operations.

What role does data-driven production planning play in enabling operational excellence and smarter manufacturing decisions?

Production planning becomes far more effective when it is connected to real-time operational intelligence. In the sugar industry, planning begins well before production starts. Cane availability, crop maturity, expected crush volume, feedstock quality, sugar recovery expectations, logistics and market demand all influence planning decisions. Once the season is underway, the operating reality keeps changing: crushing rate, process stability, steam availability, boiler load, equipment condition, ethanol route selection and downstream performance all affect what the plant can actually deliver.

Data-driven planning helps reconcile the production plan with plant reality. Instead of relying only on a static plan, AI can continuously update operational expectations based on what is happening in the mill or distillery. It can help answer questions such as:

What output is realistically achievable under current conditions?

Which operational bottlenecks are limiting performance?

Where is process instability likely to affect the production plan?

What corrective action should be taken today to protect tomorrow's targets?

The broader shift is from static planning to dynamic planning, where forecasting, plant operations and decision-making are integrated.

How can Industrial AI help manufacturers achieve sustainability goals through optimized resource utilization and reduced waste?

In industries such as sugar and ethanol, sustainability cannot be separated from operational efficiency. If a plant is unstable, it almost always consumes more resources and generates more loss. That is why Industrial AI supports sustainability in two stages: stabilization first, optimization second.

The first task is to identify abnormal variability in resource use, whether in steam, power, water, chemicals or raw material loss. If similar production levels are consuming materially different amounts of resources, that variability itself is a signal of inefficiency. AI helps establish a stable operating baseline and detect when the plant begins to move away from it. Once the plant is stabilized, AI can identify opportunities to improve performance further. In sugar and ethanol operations, some of the most important areas include steam economy, extraction loss, process water use, fermentation efficiency, distillation performance, energy balance and product losses.

For example, a decision that improves one section in isolation may create a penalty elsewhere. Increasing imbibition may improve extraction efficiency, but it may also increase the downstream evaporation load and steam demand. Similarly, a local gain in distillation may come at the cost of higher energy intensity if the plant is not viewed as a complete system.

This is where AI becomes particularly valuable. It can evaluate these trade-offs across the process chain and recommend actions aligned to the overall plant objective, not just isolated departmental KPIs. The real shift is from reporting sustainability performance after the fact to actively managing sustainability through better operational decisions in real time.

As Industrial AI continues to evolve, what will the factories of the future look like, and how close are we to autonomous manufacturing?

The factories of the future will be defined not just by automation, but by the quality of operational decisions. The most advanced plants will combine process expertise, digital infrastructure and AI into a continuously learning decision environment. I see the journey in five stages:

Visibility – understanding what is happening across the plant.

Prediction – anticipating deviations, losses or equipment risks before they materialize.

Stabilization – bringing the process back to a consistent, high-performing operating state.

Optimization – recommending the best operating choices across multiple parameters and constraints.

Autonomous execution – allowing selected decisions to be implemented automatically within clearly defined boundaries.

Today, many plants are somewhere between visibility and prediction. Some are beginning to move toward prescriptive intelligence. The next major leap, however, is the transition from stabilization to optimization. That is especially true in sugar and ethanol manufacturing, where raw material variability, utility dependence and process interdependence make consistency a major challenge. A plant that cannot maintain stable performance will struggle to sustain optimized performance.

As for full autonomy, we are not yet at the stage where complex manufacturing plants can or should operate without human oversight. The more realistic near-term model is human-in-the-loop intelligence. AI will continuously monitor the plant, detect process shifts, predict consequences, recommend stabilizing actions and propose optimized operating conditions. Operators and engineers will remain central to decision validation, particularly in high-impact and safety-critical situations. Over time, however, repetitive and lower-risk decisions will become increasingly automated. So the factory of the future is not one without people. It is one where human expertise is amplified by AI, enabling faster, more consistent and more economically sound decisions.

Closing Perspective

For India's sugar and ethanol sectors, Industrial AI is not just another layer of automation. It is becoming a strategic capability for operational excellence. The real opportunity is not in deploying AI for its own sake, but in using it to solve the most important industrial challenge: how to operate more consistently, more efficiently and more intelligently in the face of continuous variability.

That is why the most practical and valuable journey for manufacturing is from stabilization to optimization. Stabilization reduces avoidable variability and helps plants repeatedly achieve their proven operating potential. Optimization then builds on that stable foundation to unlock further gains in throughput, recovery, quality, cost and sustainability.