Opening opportunities for process optimisation

To realise the full potential of process knowledge, Trie Analytics' new digital analytics tool is designed to collect, filter and transform data into relevant information to make it available as a first step towards identifying optimisation opportunities. By using Industry 4.0 technologies and providing expert tuition, the approach has helped producers make efficient decisions and improve various aspects of plant performance.

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Huge progress has been made in the potential of Process Information Management Systems (PIMS) since their early development in the 1990s. PIMS are now much more reliable and customisable for a plant's own needs and can even be integrated easily via the Internet or Cloud. They also come, or can be used, with multiple linear regresssion analysis (MLRA), neural networks (NN), Data Mining and Time Shift software. In principle they can solve most – if not all – process, environmental and clinker/cement quality issues, providing that the user:

- knows the fundamentals of the problem and its drivers
- can use the software properly and has time to do so
- understands and respects the model's constraints/limitations.

The use of any software or modelling without solid process expertise generally leads to disaster. Trie Engenharia works with and visits many plants that have the most up-to-date PIMS from good suppliers but that are not being used to anything like their potential and could be used to improve many aspects of plant performance. Most of the time, plant personnel training on these tools is not adequate or advanced enough. Usually, training does not include enough time for them to learn and really apply what is considered an innovation far away from their reality.

Expert process help via continuous tuition/teamwork is needed to help plants get the best out of available tools, process data and the operational/maintenance team. This is where Trie Engenharia comes in with its Industry 4.0 Cloud-based data analytics system and its cement process experts networking to fully assist cement plants 24/7 in the optimisation of daily processes.

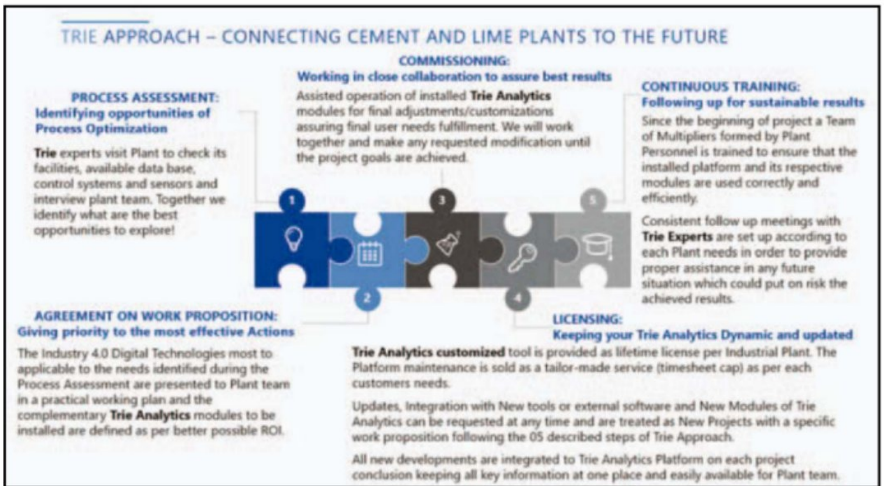

Figure 1: the five steps of the Trie Approach to connect industrial plants to the future. Once Trie Analytics is installed and operating it is not the end of the project but the beginning. A plant is not left with good hardware and software that it does not have the time to use, exploit fully and become a white elephant. This is when Trie's real job starts

Trie Analytics is a complete tool that allows process management professionals to automatically collect, filter and process multiple-source data to feed a dashboard in real time and help solve process, emissions and cement quality issues, incorporating artificial intelligence (AI) and big data into the decision-making process. This leads to more efficient decisions and, consequently, higher ROI.

The analytics tool has helped cement and lime producers implement a real Industry 4.0 policy that fulfils their needs with not only science and technological tools but by guiding plant personnel towards a process knowledge-driven, problem-solving culture.

Why Trie?

Trie is an efficient information reTrieval data structure which brings an optimal limit for the storing of data and search complexities, and can be readily customised and fitted into any industrial plant. With Trie, searching for information is faster and storage takes up less space.

Trie Engenharia considers transforming data into relevant information, and quickly and efficiently making it available as the first step to enable people to optimise industrial processes. This is how the Trie digital tree concept is applied to optimise cement and lime plants when combined with unique process knowledge, plant training and Industry 4.0 technologies.

Figures 1 and 2 summarise the successful approach in applying Trie Analytics.

Practical application

Trie's process experience allows it to help a plant in many areas, including:

- kiln burner, calciner and SO_3 and Cl cycle optimisation and bypass specification needs
- achieving 100 per cent petcoke and alternative fuels and raw materials (AFR) use through pre- and co-processing optimisation
- kcal/kg reduction through cooler and preheater optimisation
- NO_x reduction via reburn and staging, plus CO, VOC and HCl reduction through process know-how
- high-level control improvement of real run-time and operator uniformity
- clinker quality, 1- and 28-day strength, setting time and workability
- CO_2 reduction via improvements in process operation and strength enhancement allowing more limestone or other extender.

Trie can sit on top of any distributed control system (DCS) and/or PIMS with some customisation and be operating within one month of the get-go. During this time detailed discussions with the plant team as well as analysis of existing data are often arranged to develop a preliminary understanding of the potential dashboard needs for various levels of plant operation and management as well as potential process issues.

Examples of some typical dashboards are shown in the case studies below, which

Figure 2: the structure and main features of Trie Analytics, which are all combined in the Trie Approach, are designed to produce both general and customised plant solutions for any process and management related issues

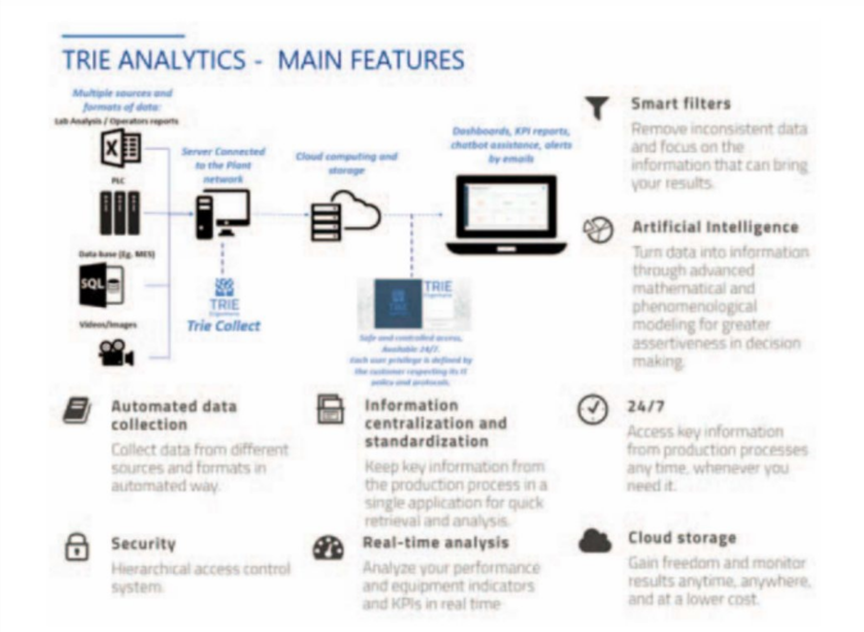

Figure 3: Trie Analytics' production manager dashboards for kiln KPIs – (a) compares the performance of operators as per the main KPIs defined by the plant manager over one month, (b) shows kiln KPIs on a monthly average and are coloured according to plant goals

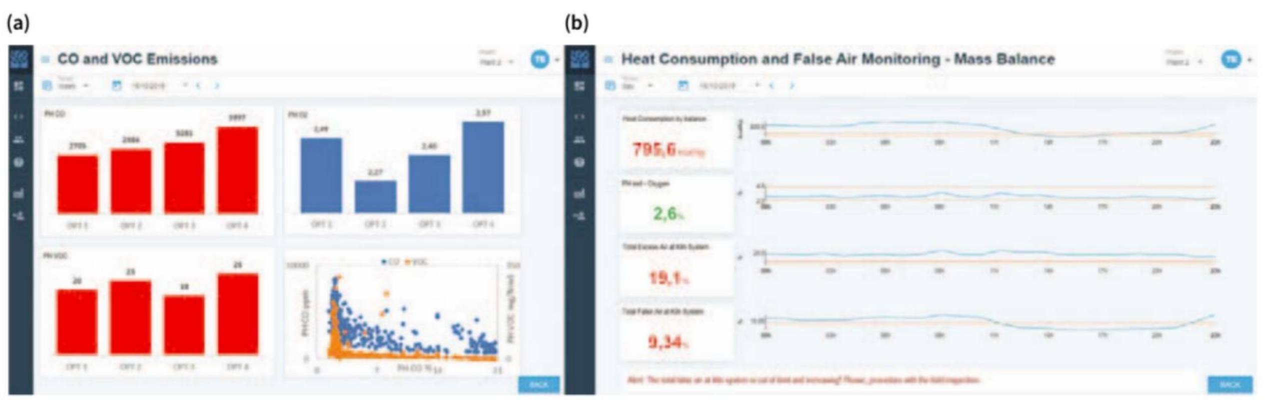

Figure 4: Trie Analytics process engineer dashboards: (a) shows the monitoring of CO and VOC emissions, and (b) evaluates total false air into the kiln system by mass balance and its influence on specific heat consumption

give practical examples for different levels of management from current projects.

Case study 1

Identifying best operational practice, increasing the thermal substitution rate and reducing production costs

In case study 1 Trie Analytics was initially set up in a cement plant to allow the plant manager – who was temporarily managing two plants located in close proximity of each other – to quickly, easily and reliably access the main kiln KPIs of each plant remotely. The plant was focussed on increased alternative fuels use and, at the same time, reducing SNCR operational costs while keeping NO_x emissions and kiln output under the established limits. Within 20 days of the project's kick-off meeting the main dashboards were available for the plant's whole technical team, and weekly follow-up meetings with Trie experts began.

As demonstrated on the dashboard in Figure 3a, Trie Analytics had shown a high usage of expert process control system (at least 97 per cent of the time) for all operational teams.

However, Team 2 achieved lower level of NO_x emissions at less cost in terms of SNCR.

In theory, when any process is being operated by an expert control system most of the time no one would expect significant differences between operator shifts. However, it is important to remember that any technology and all tool performance will always depend on how people use them. In this case the operators achieved better results by using their own experience and overriding the control system – as many as 30 overrides per shift were found. In this case the expert control system was not functioning correctly in its prediction of free lime and needed predictive help in tuning from Trie.

By applying time-intelligence built into Trie Analytics, which allows for the fast and efficient analysis of an entire database at any time step, it was possible to identify the best practices that were leading to better results for each KPI. From the follow-up meeting an action plan was designed and implemented by the plant's technical team and supported by Trie experts to achieve the results summarised in Figure 3b. The result was a reduction in total clinker production costs by increasing the thermal substitution rate (TSR) and keeping NO_x emissions under the limits using approximately 46 per cent less urea.

Case study 2

High CO and VOC emissions with AFR

Case study 2 started as a consultancy project. The plant was well above 500ppm CO and 10 VOC stack emission limits. The first comparison showed that all operational teams ran the kiln well above the limits. Then a detailed process study showed that:

- The secondary combustion chamber was operating under sub-stoichiometric conditions.
- The AFR quality control was poor and the alternative fuel used was too large. Some volumes were falling onto the kiln feed shelf.
- The AFR feeding system was not delivering a steady feed rate.
- The preheater was running at very low oxygen levels and no history of false-air monitoring was available.

The short-term solution was to increase the preheater oxygen guide value above four per cent to contain most of the high VOC and CO excursions. Longer-term actions included modifications to the AFR handling system and pre-processing quality control, followed by modifications to the riser duct to locally increase gas

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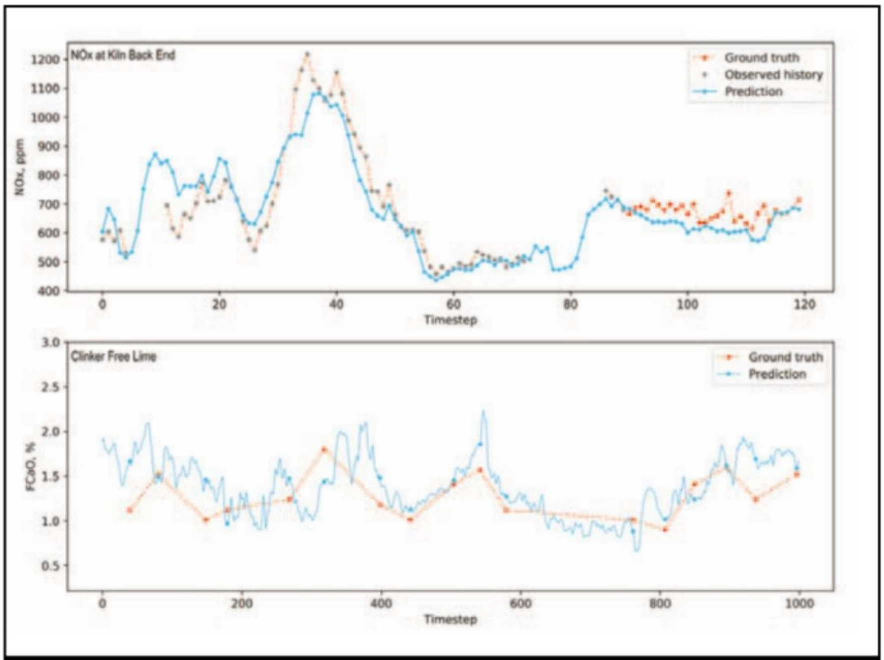

Figure 5: Initial development of NO_x emissions and free lime predictions by AI dynamic modelling

velocity to stop the AFR drop-through and improve mixing with the flow from the combustion chamber.

Following the initial diagnostic study and, complementary to the implementation of its action plan, Trie Analytics' customised dashboard (see Figure 4) was designed with specific email alerts to assure the consistent monitoring of root causes to prevent the previous problems from returning. Trie Analytics' email alerts can be customised by alert cause, time intelligence and plant team hierarchy to evaluate situations according to the importance of the monitored phenomena.

Case study 3 – using AI

From free lime to kiln emission predictions

Usually, after a couple of months of operation of Trie Analytics assisted by Trie experts, there is enough data for artificial intelligence to be brought into play.

At this point Trie Analytics can go beyond the computation of KPIs over the past data. With the help of recent data mining and machine-learning techniques, such as deep-learning, the system is provided with the AI-driven dynamic process model. This model follows a holistic paradigm and is capable of tracking complex mid-term relations between hundreds of measured variables, which are proving to be very useful inputs in improving existing kiln control systems.

Unlike common, off-the-shelf machine learning algorithms, the Trie Analytics platform is architectured with industrial applications in mind and can automatically handle missing or corrupted data from malfunctioning sensors.

When complemented with expert knowledge, the AI model can be used in a variety of ways, such as:

- detection of anomalies or abnormal operating conditions for further investigation
- predicting failures or rare events beforehand, such as stoppages caused by high build-up levels
- scenario analysis of operator and control-system actions
- real-time guidance for plant operation to achieve optimal production performance within the constraints.

Figure 5 shows examples of predictions of NO_x emissions at the beginning of dynamic process modelling development. For NO_x emissions, 2.5h of operational results were being predicted by applying deep learning techniques and process data collected 7.5h beforehand. The clinker free lime predictions were carried out using only three days' worth of operational data and during very unstable operating conditions, just before a kiln stoppage.

Such challenging conditions were chosen for this example to demonstrate the huge potential of the AI model as it was possible to predict the trends of such complex process with few data and under unstable operating conditions. Significantly-better results are achieved when proper conditions and the whole dynamic process modelling development is complete, opening up several opportunities for cement process optimisation which are appropriately chosen during Step 1 of the Trie Approach, as described in Figure 1.

Helping plant performance grow

Trie is at the beginning of a journey to help plants improve performance with process, emissions, AFR and clinker quality issues, via its dashboards, expert process knowledge and advanced AI within the Industry 4.0 framework. With the Trie roots now firmly planted it can help any plant's performance grow – fast. ■