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Intelligence of equipment and control systems at pulp and paper industry enterprises

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Abstract. The issues of intellectualization of equipment and control systems at pulp and paper industry enterprises are considered. The features of digitalization at large pulp and paper mills are shown. An example of the implementation of an intelligent system for assessing the functioning of technological equipment at one of the pulp and paper mills is demonstrated. The main sources of efficiency of intellectualization and intellectualization of production and automated systems are shown.

1 Introduction

In connection with the fall in prices on the market, the issues of increasing the efficiency of the functioning of technological equipment are becoming increasingly urgent for enterprises of the pulp and paper industry. They are especially acute due to the fact that one of the features of the Russian pulp and paper industry is the deterioration of the main technological assets. Suffice it to say that only 10% of the main technological equipment at enterprises corresponds to the modern level [1].

In recent years, the pulp and paper industry has turned to digital technologies to further optimize operations. This is partly due to market trends:

- continued pricing pressure on paper producers as the market for traditional paper products declines;
- growing demand for paper packaging as a more sustainable alternative to plastic.

Digital technologies – machine connectivity, intelligent automation, and advanced analytics – are enabling new levels of productivity in the pulp and paper industry by leveraging large volumes of production data to generate better insights and results. Successful digital innovators report productivity gains of 5 to 10 percent, productivity gains of up to five percentage points, and significant savings in materials, chemicals and energy. This represents a $4 billion to $6 billion opportunity for the industry, and that value is achievable here and

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now. More than 25 unique use cases are already creating value across the pulp and paper value chain [2].

Forestry and logistics can see the benefits of applications that track the flow of materials from harvester to mill in real time to help optimize delivery and scheduling. In pulp mills, companies are using advanced analytics to improve kappa number control and improve fiber yield. In paper mills, optimizing energy consumption, solving key problems with AI, and optimizing speed increase profit per hour. Finally, in finishing, advanced analytics drive quality improvements [3].

Companies that maximize ROI from digital investments do three things well:

1. Developing a strategic roadmap to capture value and implement the right technology tools. Companies must clearly articulate the overall value potential of digital technologies and how they plan to capture that value over time. A strategic roadmap helps ground the organization in the sequence of value initiatives as well as the technology enablers that need to be implemented (such as sensors, data pipelines, and storage) to take advantage of the opportunity. The goal should be to manage the program according to a clearly defined business plan with targeted key performance indicators (KPIs) and avoid technological experimentation.
2. Creating new opportunities within the company. Successful digital transformation requires new skills and new ways of working. Companies can supplement their workforce with outside contractors to get started and gain momentum; however, they must create these new capabilities in-house if they want digital transformation to be scalable and sustainable. To get maximum value and improve implementation results, companies need to combine technology and data expertise with core processes and operational decisions that cannot be integrated through a software interface. This requires serious attention to recruitment and systematic development of people.
3. Change Management Master. Digital solutions are of no use if they are not adopted and used every day in the workplace. For this to happen, organizations must focus entirely on the end users of technology and spend time understanding their needs and incorporating their feedback. Equal attention must be paid to both learning and reinforcing new behaviors and deploying new applications.

Separately, I would like to note that increasing the profitability of an enterprise may depend on an in-depth analysis of the existing operating system of the enterprise. For example, in works [4, 5], the authors show methods of system analysis to improve the efficiency of mining enterprises. The use of technical models, as shown by Professor Ilyushin Yu.V. [6,7] can create the basis for modernizing a stand-alone production roadmap [8, 9].

2 An example of the implementation of intelligent systems at the Segezha pulp and paper mill

Let us consider an example of the implementation of intelligent systems using the example of the implementation of a system for assessing the functioning of technological equipment. To quantify the efficiency of using technological equipment at an enterprise, the OEE indicator (Overall Equipment Efficiency) is used, designed to control and improve production efficiency and based on the measurement and processing of specific production parameters. Thanks to the OEE indicator, with the help of simple calculations and analysis, you can get an answer to the most important question for any enterprise manager: how to quickly and significantly increase product output without introducing additional capacity. By opening the “black box” of production losses, the OEE indicator allows us to identify problem areas in the enterprise [10]. Criteria for overall equipment efficiency used at pulp and paper enterprises. Shown in Fig. 1.

Fig. 1. Criteria for the overall efficiency of equipment at pulp and paper enterprises.

The OEE indicator includes three performance criteria. The availability criterion takes into account losses associated with equipment downtime and includes any stops that are not a stage of the work process: breakdown and failure of mechanisms, their maintenance (scheduled and unscheduled), stops due to shortages of raw materials, etc [11].

The productivity criterion takes into account losses associated with a decrease in production speed and includes all factors that cause a decrease in the operating speed of equipment compared to the maximum possible. Loss of productivity can be caused by equipment wear, the use of poorquality materials, incorrect feeding or operator ineffectiveness, and poor quality energy.

The quality criterion takes into account material losses that occur due to the production of products that do not meet certain standards. In the pulp and paper industry, these may be losses when cutting edges of paper tape, rejected rolls, losses when changing grades, losses when breaking the tape, etc.

In international practice, it is generally accepted that an OEE is less than 65%, satisfactory – from 65 to 75%, good – more than 75%. It should be noted that the OEE indicator for world industrial leaders is 80–85% [12].

Assessing the situation in the pulp and paper market and realizing that in order to achieve long-term advantage it is necessary to take new steps in business reform, the management of one mill initiated a project to implement a real-time OEE monitoring system on one of the enterprise's paper machines. The main focus of the project was to improve the operating efficiency of the equipment and increase the OEE from the initial value of 69%, at which production was not profitable.

2.1 Implementation of a project to implement a system for monitoring the OEE indicator in real time

Before the initiation of the project, the enterprise had a “manual” system for monitoring the efficiency of using technological equipment. Operators had to manually enter each downtime and its reasons. Logs were kept and consolidated in Excel files, the results were generated and analyzed only at the end of the week or month. Moreover, recording some events with a “manual” control system is a practically impossible task, since the speed of the technological process is too high, and the volume of incoming information is too large for human perception [13].

The introduction of a full-fledged control system should have allowed:

- track in real time losses of time, productivity and materials based on hourly summary indicators displaying actual and standard values of technological indicators;
- automatically register events based on signals from the automation, recording the start and end times so that not a single event is missed;
- publish reports analyzing the causes of downtime, decreased productivity and loss of materials for any period of time on the enterprise local network with access via Internet Explorer.

In accordance with the requirements of the technical specifications, it was necessary to provide for the presence of an archive of production data in the control system, which receives signals from automation systems. All events related to the efficiency of process equipment were to be recorded automatically, with start and end times recorded.

To select and enter reasons for downtime, the operator had to use a three-level drop-down list with the ability to add comments to each event. To calculate some types of material loss, it was necessary to provide a link to the order tracking system (for example, rolls to transfer data on loss to edge trimming). When recording downtime of a certain type, material losses should have been automatically recorded and calculated. Based on the results of each hour, indicators had to be calculated, based on which reports could be generated at the end of the day and month. At the same time, users should have the opportunity to select machines, product types and time intervals at their discretion, after which a full or detailed OEE report would be generated [14].

The transition from a manual calculation system to a real-time control system initiated the first technical challenge of the project: the values in the daily reports of the old system and the calculations performed on the paper machine based on real-time data did not match. The second difficulty was that due to the transition to a real-time control system, more precise data filtering was required [15-18].

The project lasted four months, three of which were spent on developing the system and one on setting up calculation algorithms and data filtering.

The third challenge that the company had to accept was the need to recalculate indicator values after making some new decisions. For example, if for some previously recorded downtime the reason changed from “Maintenance” to “Setup”, then the values of the summary indicators previously calculated for this machine for the reporting period had to be calculated again, taking into account the change in the source data. If changes were made to the data for the previous month (quarter), then it was necessary to recalculate the values for the corresponding monthly (quarterly) indicators.

The company needed a high-level MES system that would be able to:

- automatically collect data from automation systems;
- identify causes of downtime;
- publish fully functional interactive reports on the Intranet/Internet;
- recalculate summary values based on historical data without stopping work.

To implement the assigned tasks, the Proficy Plant Applications software package from GE Intelligent Platforms was used, which is a platform for deploying a production process management system at an enterprise. The system was correctly deployed, implemented and ensured that all the above requirements were met. Proficy Plant Applications: is a system for improving production processes, and Proficy Plant Applications is a production analysis and management system based on the Proficy software product from GE Intelligent Platforms.

Proficy technology is perfectly adapted to mixed types of technological processes in the pulp and paper industry: pulp production - continuous or batch process; paper machines and coating machines – semi-continuous process; cutting sheets and forming paper products - the transition from a continuous process to a discrete one; packaging is a discrete process [19].

Developed by GE Intelligent Platforms, the software connects process control systems to business systems and provides a proven solution for manufacturing management and optimization (MES), enterprise intelligent manufacturing (EMI), quality control and compliance.

2.2 Results of the project to implement a real-time OEE monitoring system

The first result of the project to implement an OEE monitoring system was time savings. Operators no longer spent working time collecting data, performing calculations and discussing the reliability of source data and calculation results, but were busy performing their direct job responsibilities. In addition, the enterprise now has a picture of the current efficiency of operators' actions, which makes it possible to more accurately evaluate the work of personnel.

The second result of the implementation of a system for monitoring the OEE indicator in real time was the ability to influence the technological process in real time, and not after the fact, after the next reporting period. A decrease in productivity with recording of the reasons for downtime was quickly identified by the system, as a result of which certain corrective action could be taken almost immediately [20].

But the most important result was the increase in paper machine efficiency, which was measured by the OEE value. The implementation of the project after just six months made it possible to increase the OEE indicator by 7% - from the initial value of 69% to 76%. Today, the paper mill continues to improve operations based on incoming data on the root causes of downtime, lost productivity and quality issues. Performance data is archived for future long-term analysis. Currently, the mill management is considering a project to expand the system to other paper machines and paper pulp production lines [21-22].

All this encourages factory management to either purchase new modern equipment and expand production, or modernize existing equipment, bringing it to new efficiency indicators.

However, in both the first and second cases, not every manager can answer the question - is the technological equipment being or will be used effectively at the enterprise? Moreover, it is important here not only to answer, but also to justify your answer with quantitative indicators.

Currently, at the JSC Segezha Pulp and Paper Mill, the final implementation of a system that predicts the occurrence of defects and stoppages of paper-making equipment based on predictive analytics using machine learning (ML) methods, developed by the Jet Info systems company [23].

One of the main challenges for pulp and paper production is the breakage of the web moving through papermaking machines. Web breakage is a big problem in both old and new paper mills. Even a minimal stop of the production line once a day on a scale of one year means long equipment downtime, additional consumption of raw materials and significant financial losses.

To solve the problem, the Machine Learning Center of Jet Info systems built ML models that analyze data from equipment sensors and indicators of automated process control systems related to equipment maintenance and replacement of materials. The system detects different alarm levels and provides an indicator of the likelihood of a web break or line shutdown, predicting the date, time and possible cause of the damage. The analysis results are displayed on the monitors of the machine operator and the technologist on duty.

Machine learning algorithms identify: sensor indicators that can cause equipment shutdown and complex dependencies, for example, when the readings of some sensors begin to influence only if others are outside a given range. The key value of solutions using predictive analytics for a technologist is the ability to prevent machine stoppage or breakdown, as well as to predict the most typical stoppages, in particular for the most common type of stoppage - breakage. And for the business owner, this is a guarantee of continuity of production and reduction of financial losses.

Thus, intelligent automation makes it possible to integrate processes, not just systems and applications; provides the possibility of comprehensive automation instead of manual, and much more expensive, work performed by people. It provides objective indicators (actual, reporting, and analytical data) of compliance with established indicators. It reduces training costs by eliminating the need to understand the sequence of steps, but still ensures that they are followed exactly. Instead of a "black box" back-office information system, every transaction, process step and data element is automatically controlled by business rules [24].

With the accumulation of data that provides stronger and more accurate sampling in the face of uncertainty, additional opportunities arise in coordinating the end-to-end process, managing the sequence of steps, and monitoring the state of the process as it moves from one step to the next. Over time, as explained data is obtained and structured into explanatory and advising (expert) mechanisms, and a better understanding of how work should be performed, the reach of intelligent automation can expand to tasks previously performed by human workers [25-29]. Further developments will obviously lie in the plane of advancing the Industry 4.0 technology into the real production of pulp and paper mills [30-37].

3 Conclusion

Intelligent automation offers the promise of greater productivity, coupled with greater transparency and better adherence to established policies. The ability to integrate not systems and applications, but processes, the ability to automate comprehensively instead of manual (much more expensive) work performed by people is what makes intelligent automation so attractive.

The example of the development of the usage of intelligent systems at the Segezha Pulp and paper mill clearly demonstrates the possibilities and difficulties that may arise when implementing intelligent automation systems. First of all, it should be noted the importance of defining the goal, which should be the core of the system and relative to which the subsystems and elements of the intelligent system will be deployed. The OEE model plays a significant role here. OEE technology also requires the allocation of the most important functions and criteria for the overall efficiency of the equipment. Another important aspect is the prioritization of functions, for example, the importance of an archive of production data.

The transition from manual calculations of paper machine data to a real-time monitoring system is a serious technical challenge in the implementation of intelligent systems at the pulp and paper mill. A full-fledged system also requires the interconnection and integration of all data and information with higher-level systems (MES). A significant role in ensuring the solution of this problem can be played by the Proficy Plant Applications software package, which has proven itself well at the Segezha Pulp and Paper Mill, as well as the introduction of modeling of the main types of defects and losses in the operation of a paper machine, causing downtime and reduced efficiency.

The future of the intellectualization of pulp and paper production is seen in further comprehensive automation, in the growth of the number of data collection points and the presentation of structured information with the provision of predictive analytics at all levels of management from the technologist to the management of the enterprise.

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