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VIP - Intelligent Production Surveillance: An Innovative Approach for Second Layer Monitoring in the Oil and Gas Industry

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Abstract
Professionals in the oil and gas industry are experienced in dealing with alarm systems for first-layer monitoring, which refers to systems where the operator monitors and operates the plant simultaneously. These systems typically have limitations when it comes to implementing more advanced solutions for detecting anomalies, such as artificial intelligence algorithms. Moreover, solutions implemented for one oil production platform often lack scalability for deployment on other platforms. To address these challenges, Petrobras has developed VIP - Intelligent Production Surveillance, an alarm system designed specifically for monitoring oil producing wells in the second layer. The users of this system are specialists in well performance, artificial lift, and flow assurance, who work onshore and provide real-time technical support to the operators on board the platforms. VIP incorporates typical functionalities found in industrial alarm systems, such as recognition, timers, suppression, and prioritization of alarms. However, what sets VIP apart are the advanced algorithms embedded within the system, enabling it to detect specific abnormal events. Additionally, the system utilizes a contextual database, facilitating easy scalability to other platforms within the company.

Keywords
VIP; second-layer monitoring; expert alarms; artificial intelligence.

Introduction
The oil and gas industry is undergoing a significant transformation driven by increasing pressure to enhance operational efficiency and safety. In this evolving landscape, rapid response to operational issues is crucial. However, traditional alarm management systems, such as automation layer-based supervisory systems, are showing their limitations and becoming insufficient to meet current demands.
Automation layer-based alarm management systems have been widely used in the oil and gas industry to monitor and control real-time operations. However, as the complexity of operations increases and the need for advanced analytics becomes essential, these systems prove limited in their ability to support data-driven and AI-based alarms [1] [2]. Moreover, scalability becomes challenging as the volume of assets and operational complexity grows.

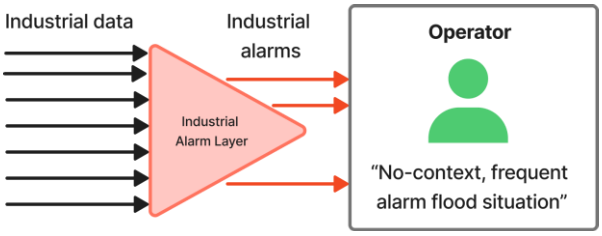

Fig. 1 - Common scenario with traditional industrial-layer alarm systems

In this context, there is a need for an innovative solution that can handle the scaling of operations, incorporate advanced alarms based on data analytics and AI, and provide a secure and efficient environment for decision-making [3] [4] [5]. This is where the VIP - Intelligent Production Surveillance - system comes into play.

Methodology
Developed by Petrobras, the VIP system functions as a second-layer monitoring tool, complementing first-layer supervisory systems. It differentiates itself by reconciling industrial and expert monitoring

techniques through the combination of AI algorithms and data science. Instead of replacing the industrial layer, the system leverages the expert layer, utilizing expert alarms to identify unwanted events and suppress associated industrial alarms.
To unite both the industrial and expert layers, the system utilizes the same alarm evaluation flow used in first-layer alarm systems but applied to the second-layer. The main differentiating point is the industrial alarm suppression logic, which uses the existence of an expert alarm to suppress industrial alarms that are correlated to it.

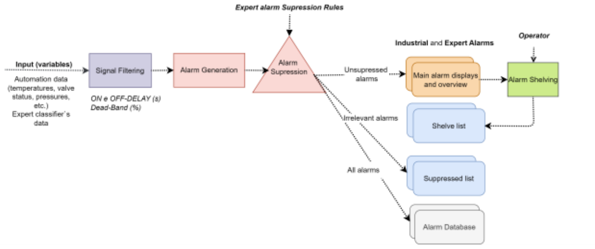

Fig. 2 - Overview of VIP Alarm System architecture

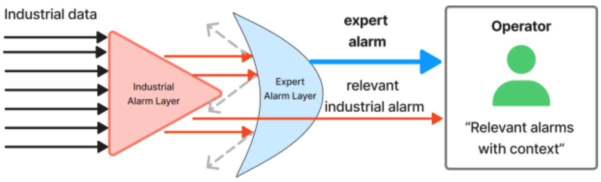

Fig. 3 - VIP System integration of expert and industrial alarm layers

Several expert alarms were developed, based both on hand crafted logics and on AI algorithms. All undesired events mentioned on [6], such as abrupt increase in BSW, flow instability, rapid productivity loss and hydrate in production line, to name a few, were implemented, as well as newer developments: partial ruptures in production lines, undesired gas inflow in water injection wells and pipeline rupture during bullheading operations.
The AI algorithms, when applied, ranged from trivial applications of off-the-shelf machine learning Python packages (*scikit-learn*'s implementation [7] of Support Vector Classification and Random Forests [8]) to more sophisticated time series processing and classification tools. The algorithms' performance metrics broadly vary between applications, depending on the modeling approach. An example of model development and metrics evaluation is given in [9].
The VIP system utilizes an open and flexible architecture, enabling integration with other expert systems. The workflow is as follows: the expert systems receive the updated industrial context layer from the VIP system, which serves as the basis for expert analysis. The expert systems generate their analyses using a multivariate approach and store them in a data historian. The VIP system continuously ingests these data from the historian and processes the alarm, evaluating if it should suppress other industrial alarms and applying industrial design techniques to effectively communicate its priority and recommended actions.
To scale the solution, we created, in collaboration with area specialists, a parameter dictionary with easily recognizable acronyms to identify industrial variables typically available in well instrumentation. This data dictionary, in turn, served as a basis for specialists from each business unit to list the unwanted events they wished to detect and then choose the best event detection strategy, using AI and data science techniques appropriate to the team's expertise and the context and data available in each case.
The classifier can then be trained, put into operation, evolved, and scaled to more wells completely independently of the alarm management system. The bridge between the classifiers and the alarm system is made through storing the classifier's results in the data historian tags, which are then processed by the alarm system, potentially generating expert alarms, which in turn are used in suppression rules.

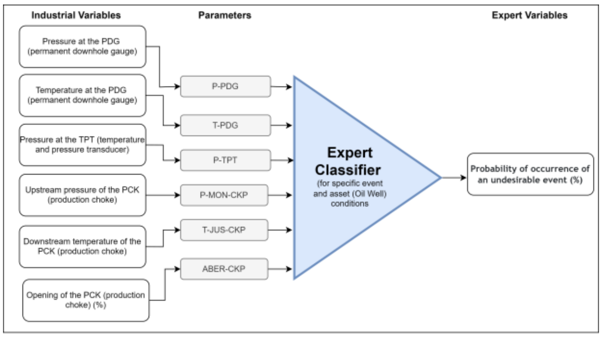

Fig. 4 - Example of expert classifier inputs and outputs

Among the main challenges encountered, we highlight the difficulty in defining a unique expert logic for each unwanted event. Considering the scalability challenges, the approach taken was to empower specialists from each business area to build and publish their own classifiers, simply by following the common data dictionary and registering a new variable in the historian. The IT sector was sensitized to create and maintain a classifier publication pipeline, allowing the combination of domain experts' expertise with the robustness and security provided by IT specialists.
By reconciling the industrial and expert alarms, the VIP system has proven to be an effective approach in enhancing alarm management. It facilitates the incorporation of specialized expertise while maintaining the value of industrial context data. This innovative methodology contributes to a more efficient and accurate alarm prioritization process, facilitating effective decision-making in real-time operations, while continuously expanding the monitoring scope.

Results and Discussion

The VIP system, which has been used by Petrobras well production monitoring teams since 2015, has demonstrated its effectiveness in detecting unwanted events, utilizing both industrial

and expert alarms. The expert alarms, integrated into the system through variables that employ a multivariate approach to diagnose anomalies, have been developed using the contextualization provided by VIP itself.
Classifiers apply artificial intelligence techniques to infer the possibility of an abnormal event occurring and express it as the output of an expert variable. These variables are parameterized within VIP to trigger alarms when they reach predefined setpoints. Once triggered, the alarms are configured and treated in the same manner as other industrial alarms.

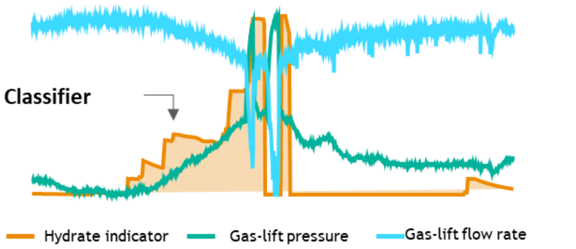

Fig. 5 - Expert classifier in operation detecting an anomaly

Since its implementation, VIP has undergone significant technological updates to meet evolving business demands. Currently, the system monitors over 600 wells full-time, with more than 40 thousand variables, including both industrial and expert variables, registered in its contextualized database. The implementation of the alarm system has resulted in significant financial gains for the company, along with indirect gains related to knowledge management.
To quantify the financial gains associated with VIP, the actions of the engineers who use the system are counted. Each type of abnormality detected and treated represents a gain (avoided loss), which is defined according to the well's production potential and a time assumption based on history. For example, each action to treat hydrate in the service line avoids a loss of 1.5 days of well production. Of the total gain, it is understood that portions of this gain are attributed to people, processes and tools/systems. In this context, VIP represents a portion of the tools used to monitor production, being responsible for avoiding losses of around 22 million dollars per year.
Furthermore, the application of specialist alarms in VIP contributed, among other initiatives, to a considerable reduction in the number of alarms announced by the system. In one of the company's business units, the average number of alarms per day was reduced from a level of 500 to 70 alarms per day, as shown in the figure below (blue bars).

Fig. 6 – Trend of reducing announced alarms over time

Moreover, VIP has proved to be a crucial tool for Petrobras Flow Assurance Decision Support Centers, contributing to substantial achievements such as risk reduction and avoidance of production losses. It encompasses expert logics to detect hydrates in gas-lift lines and production lines, wax deposition in production lines, unsafe alignment of subsea valves, and other critical scenarios.
The following figure illustrates a binary classifier for detecting hydrates in a gas-lift line (blue curve). This expert logic identifies when there is reduction in gas-lift flow and increase in gas injection pressure. From there, an alarm is announced by the VIP, which, in turn, displays the action to be taken to reverse the unwanted scenario.

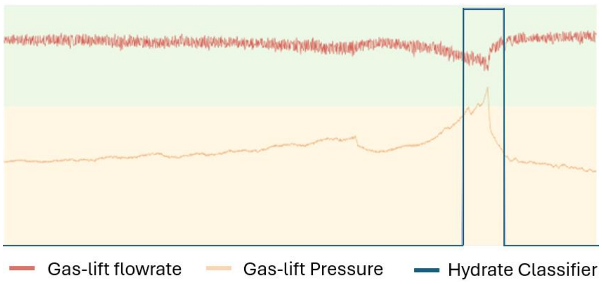

Fig. 7 - Binary expert classifier detecting hydrate formation in gas-lift line

Conclusions

The ability to contextualize industrial variables and keep it updated is crucial to domain-expert analysis. A shared alarm philosophy can be better achieved by leveraging the VIP system as a second-layer tool, because of the shared capabilities enabled. This comprehensive methodology is not limited to the oil and gas industry but can be applied across various industrial sectors. As a result, the adoption of specialized techniques in routine monitoring is very facilitated, leading to continuous data quality improvement and a more effective alarm process.

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