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GeDIg Carapeba—A Journey From Integrated Intelligent Field Operation to Asset Value Chain Optimization

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Abstract

GeDIg is a Petrobras corporate initiative to implement Intelligent Energy technologies to achieve Integrated Digital Oilfield Management with the sole objective to maximize the life of mature and new producing oilfields. Carapeba is an offshore brownfield located in the Northeast area of the Campos Basin, comprising of 3 fixed platforms with 41 wells producing from three zones (all dry completion and equipped with Electric Submersible Pumps) and 4 water injection wells.

The key business driver is to increase the recovery factor by improving reservoir sweep efficiency with installation of ten intelligent completion systems, achieve production optimization and augment operational efficiency by upgrading field automation and integrated process optimization.

GeDIg Carapeba encompasses end-to-end seamless integration, spanning across various functional groups of the asset, integrating operational processes (fast, medium & long loops). It provides a toolset that gives the ability to make better informed decisions by multi-disciplinary teams in a specially designed collaborative environment to plan, monitor, control & optimize operational processes, making asset teams more agile. The solution is delivered through a portal platform which integrates information from Production Operations, Geotechnical and Financial systems, providing an information hub for the entire asset operations, shielding complexity of underlying sub-systems and empowering end-users with right information in-time. This is supported by field automation, smart simulation and optimization tools which integrate the well-bore, surface facility networks, reservoir, process and economic models. This level of integration provides more transparency to understand engineering and economic impact of various field development decisions.

This paper describes experiences and challenges of the GeDIg Carapeba project from conception thru implementation, integrating people and processes with the right balance of technology across field operations and how it has resulted in enhanced operational efficiency and recovery factor, coupled with a substantial increase in production.

Introduction: The GeDIg, end-to-end seamless Integration from Sensors to Asset

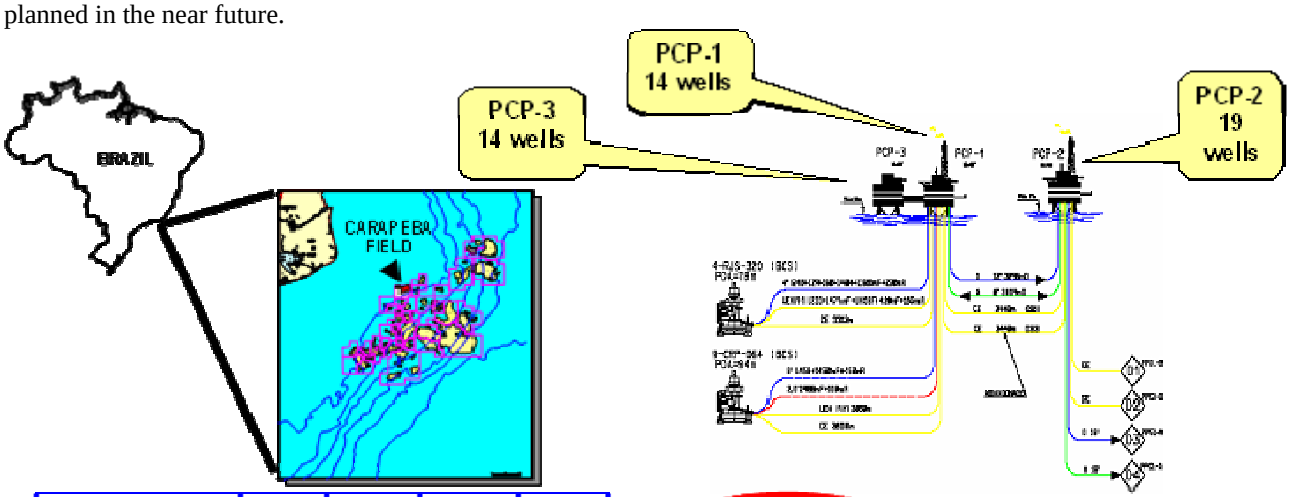
The exploration and production segment of the oil and gas industry has employed technology and processes to optimize production rates, minimize cost and improve ultimate recovery rates for oil and gas in-place since the first day of production. Over the past decade, these efforts have been termed by different parties as Digital Oilfields initiatives [1].

These efforts have many things in common:

1. The realization that the discovery of new, large reserves is becoming more and more difficult has focused attention on optimization of results for the proven and probable reserves in-place. This coupled with increasing demand and higher resource prices have allowed capital to be deployed to optimize production results.
2. The increasing reduction of size, costs and power consumption of computing devices has broadened the application of the devices. An important element of these GeDIg concepts is the deployment of real time sensors from sand face to fiscal meters enabling the real time monitoring of the oil field.

3. Software advances have allowed the creation of models that can more accurately simulate the behavior of complex physical systems such oil and gas reservoirs, wells, gathering networks and processing facilities. Another key element of GeDIg is the use of sophisticated models in the planning, surveillance and optimization work flow processes.
4. The aging of the oil and gas work force and associated scarcity of experienced resources has made techniques such as collaboration essential.
5. Communications capabilities have become available in remote areas allowing access to data about assets on a real time and on demand basis to software, people and processes through out organizations.

Petrobras has done research, discussed partnership developments with industry peers, entered in collaborative ventures with vendors and developed a comprehensive strategy to frame decisions regarding investments in Digital Oilfields [2]. The strategy framework was essential for providing the guidelines for when to use various Digital Oilfield concepts, where those concepts were applicable (different scenarios to represent the diversity of the company) and the business case required to justify the investment. A corporate program called GeDIg was established under which a series of initiatives were sanctioned to implement the strategy. One such initiative involved a technical cooperation agreement with Petrobras and Schlumberger to implement GeDIg program for the Carapeba field located in the nort-east of the Campos Basin. The field consists of 3 fixed platforms with 41 producers and 6 injectors. All the wells are dry completions and are equipped with Electric Submersible Pumps (ESP). There are three producing zones and hence has a potential for intelligent completions which is planned in the near future.



	PCP-1	PCP-2	PCP-3	Total
Oil Producers	11	16	14	41
Water Injectors	3	3	0	6
Total	14	19	14	47

Figure 1: Map of Carapeba Field and Production Concept

Solution Methodology

A critical component of our solution was a three pillared (Top-down, Bottom-up and Integration) approach during the four phases of project (Assessment, Workshop, Process Mapping and Implementation). The key three pillars ensure the collaborative relationship across all functional groups with outcomes management objective achieving tangible operational results. With a clear strategy in place from Petrobras the project began with a site assessment involving parties from all disciplines connected with the Carapeba field. Instead of focusing on particular products or technologies, the workshop focused on the purpose, success vision and process. Each discipline contributed to the picture of the “AS-IS” state of impacted work processes and the vision of the “TO-BE” state for those same processes. The output of this workshop provided the necessary input to craft a set of over fifty requirement statements which were used as basis for selection of product and technologies as well as definition of development and deployment work. Following the workshop, a value analysis was done to select the requirements with the best contribution on the business drivers and rapid execution.

The GeDIg Decision Center – A Collaborative Environment

The clear physical manifestation of the project is the GeDIg decision center – a hybrid room with integration and collaboration mix that comprises of crisis management, surveillance, diagnosis and planning room for a complete collaborative Asset decision environment as shown in Figure 2. The center was ergonomically designed taking into account the prolong usage, diverse nature of the people present and the difference in work processes involved. Surveillance concept from "NASA space flight control", diagnosis concept from medical industry was also used in the design. The various components of the center are designed to focus and share understanding for decision support and decision control. Each component is naturally linked in a collaborative environment with the decision loop timelines and the flow of the work spaces reflects the operational decision flow (problem detection, problem diagnosis, alternative solutions analysis / selection and solution implementation) and the inter-disciplinary nature of the workflows.

Figure 2: GeDIg Decision Center

On the far right is the surveillance area, where well by well alarms, alerts and variances from Key Performance Indicators (KPI's) are highlighted in a fast loop decision process. Key indicators requiring action are easy to pick out on the display. Proceeding to the left, large display screens show the results from analytical and simulation software for medium term analysis and action planning. In this area, results from many wells, gathering networks and process facilities can be analyzed. The upper parts of the displays show work flows to be executed to accomplish a particular analysis task. The next display to the left shows the reservoir models that contain the key assumptions used to plan and develop the fields. Activities that change the results in this model obviously involve long loop decision processes but coupling this with the fast and medium loop processes provides a continuous challenge to the underlying assumptions that have to be verified to achieve optimum results. Finally, to the far left is a collaboration room containing all the necessary communication facilities to bring in parties from the asset team or from any other remote place for experts opinion. The beautiful skin of the control room reflects the result of multi-dimensional integration effort that was key to the success of this project. This integration is an optimal mix between the people, technology and process.

The GeDIg - Workflow Integration

Most companies have a large set of application software from different vendors and always poses a major challenge for the success of any Digital Oilfield program. Portal technology provides an integration tool that can be used in diverse software application environments. This technology was leveraged to perform the horizontal integration across the various functions, data and application systems. At the back-end this technology was supported by an Integrated Asset Model bringing the reservoir, well and surface facility network models together to provide the "what if" scenarios.

An integration toolkit compliant with Petrobras corporate IT strategy was used as the solution back-bone for this project, which provided a set of oil and gas workflow components that work within portal environments. These components allow workflow processes to be constructed, disparate data-sources to be accessed, diverse application to be launched and all the results to be visualized in single or multiple displays as guided by the process requirements. A few of the applications and data-sources integrated as part of this project included internal production data management system, Data Historians for real-time data, wellbore schematic data, forecast production and financial information. In addition, productivity tools for efficient project planning and control are also integrated into key workflows.

Fast Loop Surveillance, Medium Loop and Long Loop Processes Examples

ESP Surveillance and Well Productivity Diagnostics

The Artificial Lift team responsible for monitoring the wells productivity and ESP operations was overwhelmed with the amount of real-time data that was being streamed to them for analysis and as a consequence they were spending most of their time surfing through the large data-sets trying to identify any potential issues. With this mind, a surveillance and diagnostics

system was designed, which will aggregate reservoir information with daily production and real-time streaming data from surface and bottom-hole sensors. This was also coupled with information from the simulation models of the wells. The set-points were defined for each well which would reflect the ideal operating conditions. All the surface and bottom-holes measurements are monitored automatically within the preset thresholds and any deviations from the ideal operational conditions are flagged as shown in Figure 3. This allows the surveillance team to quickly identify the potential issues and focus to correct them immediately. In addition, various KPI's were designed to quickly analyze the performance of well at any given period of time;

- Calculated Productivity Index (PI), Bottom Hole Pressure (BHP), Total Liquids Flow Volume (Qb) versus Time.
- Warning for wells producing below bubble pressure (Pb) i.e. BHP < Pb at the pump intake.
- Map of real-time BHP & Temperature (T) vs. Depth (well flow simulator model and real-time measurements).
- ESP efficiency plots to compare the calculated real-time head and flow rate versus its theoretical curves.
- Warning for ESP's producing below the optimum point.
- Well production incremental potential (delta Qb): Current Qb in the current productivity index curve (BHP vs. Qb).
- Pump health check: ESP Head Efficiency vs. Time.

These KPI take full advantage of the downhole sensors information and the wells which don't have downhole sensors installed were calibrated with surface well test data. Figure 5 shows the above KPI's that will allow elaboration of a list of wells for optimization and the potential incremental production in real time. In Carapeba, due to high level of sand production, production parameter should respect operational constraints, as otherwise it may damage production equipment causing unplanned downtime and maintenance. The above KPI's enable to quickly identify if any of the optimal production constraints is being violated. This proactive surveillance should lead to optimization of pump performance and extend mean time between failures, resulting in production increase.

Figure 3: Alarm detection based on deviations from preset Operational conditions

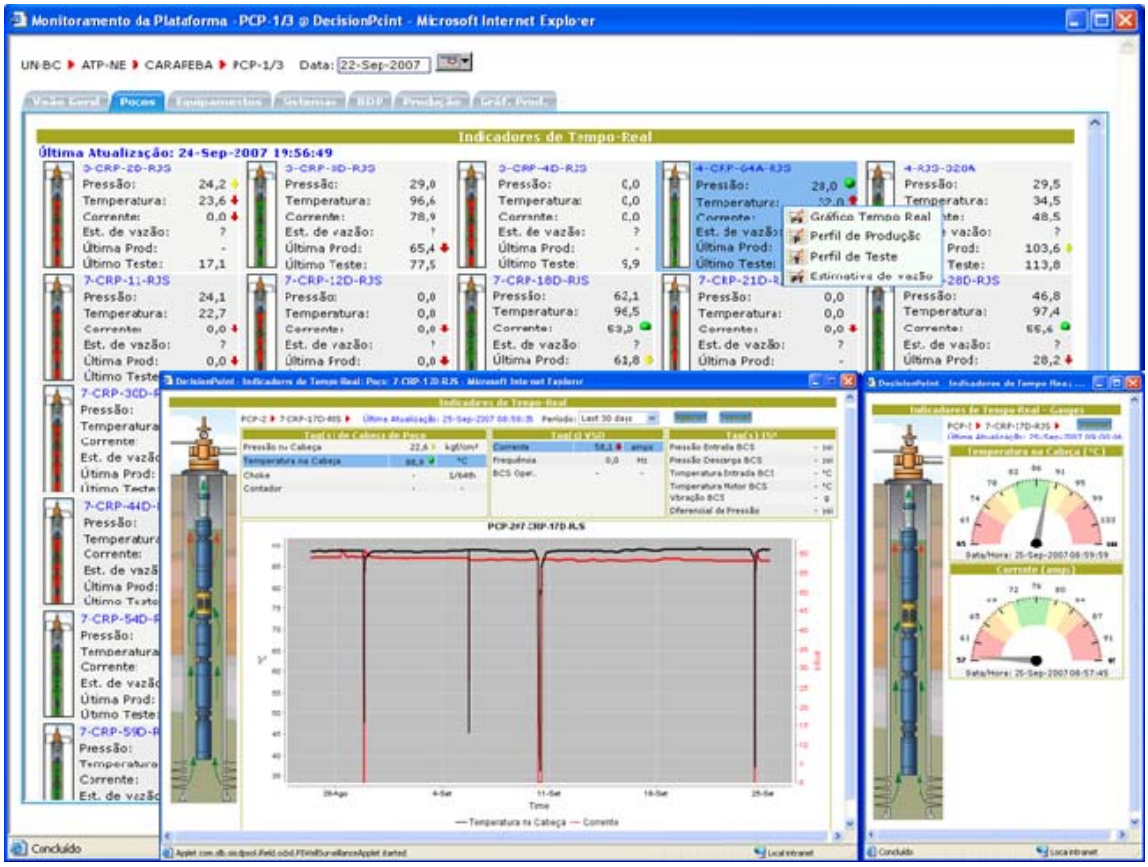


Figure 4: Monitoring ESP Parameters vs. preset Operating conditions

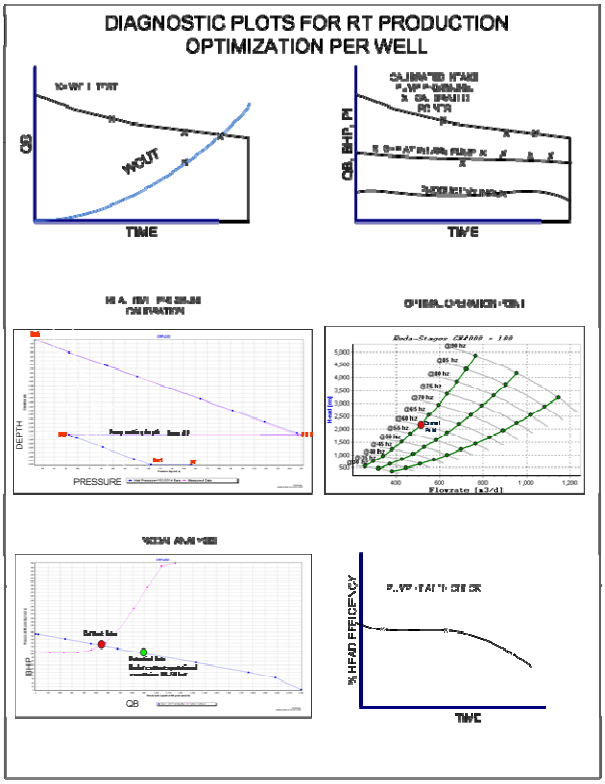


Figure 5: Surveillance and Diagnostic plots for real-time Production Optimization

Losses Management & Control

An important goal for the Carapeba field is achieving increased production rates. Differences from actual production and forecast have to be identified and analyzed so that corrective action can be initiated. Downtime and well failure cause production losses versus forecasted production rates. Historical and current downtime and failure data are extracted from internal applications. The impact of the downtime in terms of production losses are categorized by types and displayed for analysis Operations Portal (Figure 6). Trends can be analyzed and intervention activity scheduled to prevent further losses. The Open Losses tool enables identification of any losses that have not been addressed and prioritize the critical resource usage as necessary to counter the production shortfall.

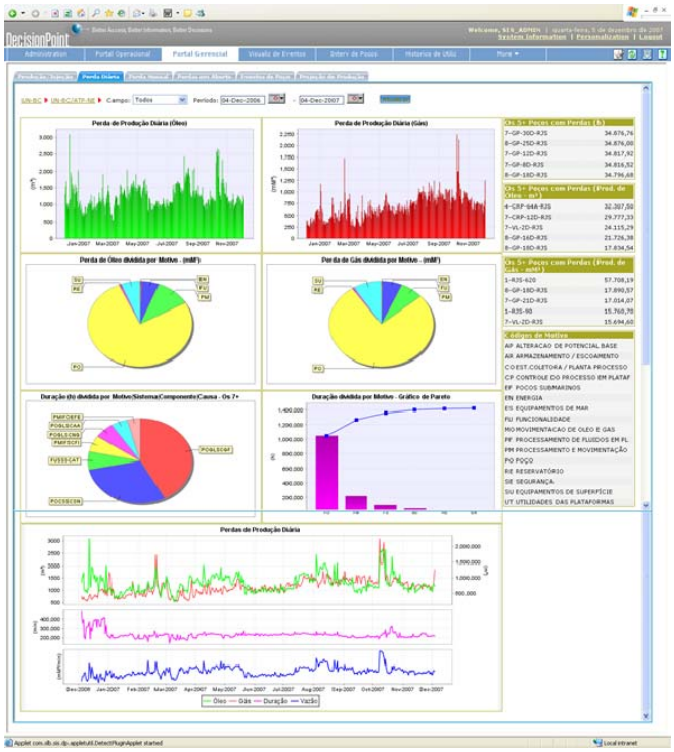


Figure 6: Analysis of Planned / Unplanned Losses

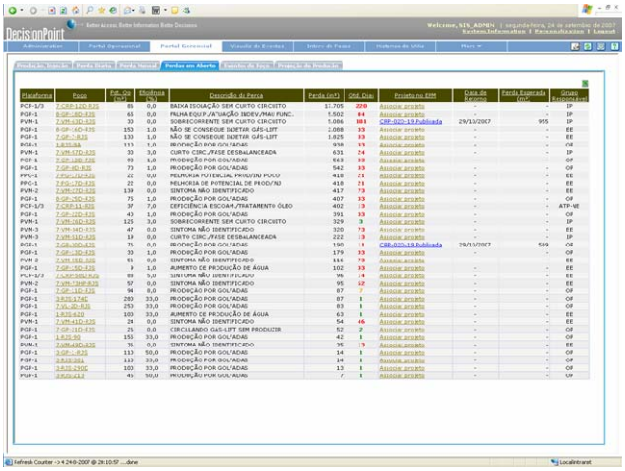


Figure 7: Open Losses Visualization and Control

Integrated Operations Management

Along with the ability to provide surveillance and diagnostics capabilities in the portal solution, it was necessary to have some Key Performance Indicators (KPI's) analysis that will ensure all the work-processes are leading to the overall value chain objective. Hence an intuitive set of management tools combining asset business view and operations view (Figure 8 and 9) was designed to give the operation managers an executive overview of the asset, with key variances from plan being highlighted.

In addition, drill-down to the true causes of any variances ensured that there was consistent information available at all levels in the asset. Human Machine Interfaces (HMI) in oil and gas applications typically shows some segment of the overall operations. The HMI provided through software portal provides a visual view of the entire field operation allowing analysis of the impact of different operations on each other. The analysis can continue past the surface to the well bore schematic. The asset surveillance view (Figure 10) combines information from ESP operations, Oil / Gas separation, power generation and various other processes – presenting an integrated view of the overall asset operations. The various functions of the asset can quickly identify the bottle-necks in the system, when a failure occurs and work to address the issues in more proactive way. As enhanced maintenance processes are a key element of increasing production rates, historical maintenance from internal maintenance system was also integrated into the overall operations view. Typically end-users monitored water injection rates looking at variances from targets. Integrated data allows end-users to look at water plant processing output along with individual injection rates.

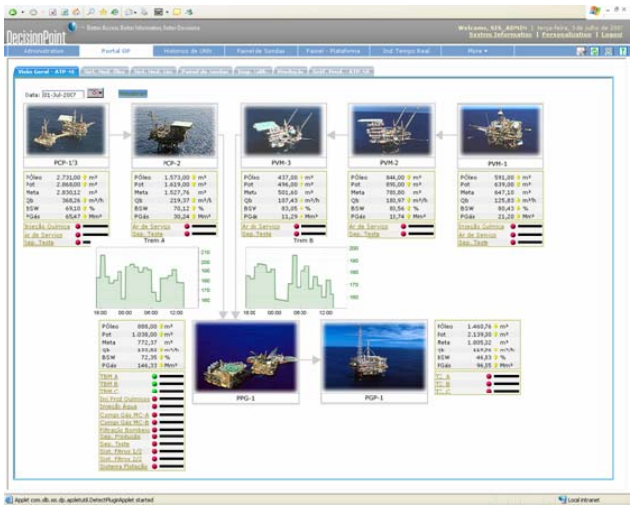


Figure 8: Asset Operations Visualization

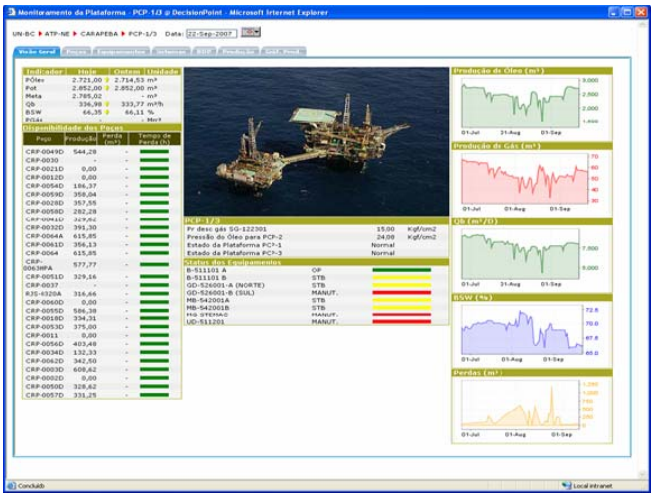


Figure 9: Platform Operations Visualization

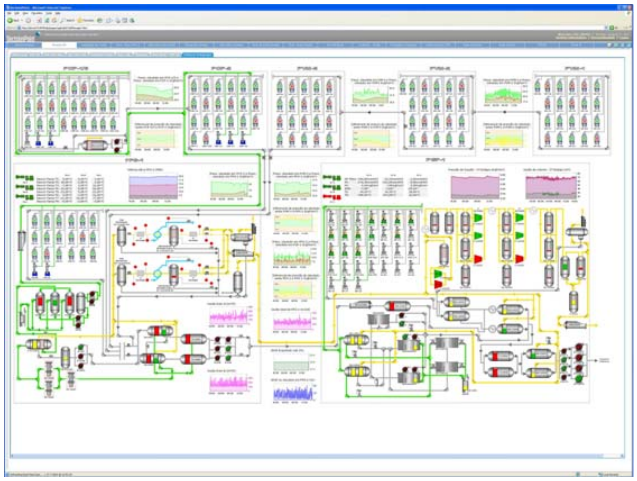


Figure 10: Asset Surveillance view with key Operational Processes

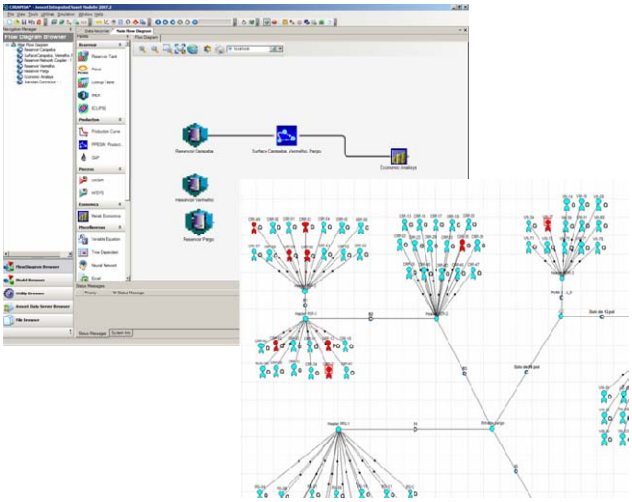


Figure 11: Integrated Asset Modeller with Well and Network Flow Simulation Model

Integrated Asset Model

Simulation models are a key component of Digital Oilfields. The models are typically constructed by different disciplines for the reservoir, the well, the gathering network and the process facility. In a typical field planning and development scenario, each discipline works for a period of time and passes a report to the next discipline with conclusions. However, the best results are obtained by running different scenarios iteratively. This can contribute to increased rates of recovery of oil and gas in place.

The Integrated Asset Modeler (Figure 11) was used to design and orchestrate models for each discipline (reservoir model, well flow model, surfaces facilities model, process facility model and economic forecast model). Recognizing the models for the different disciplines may come from different vendors; the solution needed to integrate results and provide feedback to multiple models from various vendors. This solution also enabled spread sheets to be used as proxy model inputs and allow the economic analysis of different development plans. While simulation models are most often used in the planning process, the use of proxy models allowed them to be used for optimization with real time data in the Carapeba field.

Collaboration Example

One of the objectives of GeDIg is to use technology to leverage critical resources in the oil and gas industry and one such example is of the experienced corrosion engineer. At Carapeba platform facilities, most of the offshore operators have been trained to use wireless cameras. The camera allows the operator to film equipment in various location and stream the data with a wireless connection to a corrosion engineer onshore. The operator's camera is detached from a retinal display used by the operator that allows filming tight locations without bending, twisting or other uncomfortable positions. Such collaboration activities as well as many of the elements of these projects required the development and the integration of additional telecommunication capabilities.

Key Lesson's learned

- Continuous involvement and improvement of the implementation process lead to be open to revisit the modus operandi and the implementation team should be able to quickly adapt and refine the workflow.
- Integration and early involvement of the key players combining with a clear business case definition minimize the change management effort:
    - Business case comprises the improvement areas in line with a clear vision of the asset.
    - Integration and early involvement - management buy-in with executive sponsorship (top-down), the collaborative relationship with operations (bottom-up) and the 2 ways integration in the technical specification templates– Problem statement / improvement areas (operations), expected value (management) and scope description (operations).
- Avoidance of open ended workflows with the pre-set checklist – the guided workflows (modus operandi) helps achieve focused value outcomes of the process.

Conclusion

Achieving the GeDIg vision of production rate increase, lower cost and increased rates of recovery of oil and gas in place is not easy. A clear strategy needs to be present to guide an analysis of the business processes to be mapped and modified. With this in hand, hardware, software, communications and work processes can be integrated to achieve the desired results as shown by Carapeba collaborative project. A complete system in which reliable, relevant data are used in customized workflows to improve the quality and efficiency of the decision making and management of the Carapeba field to continuously optimize production

References

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2. G. V. Moises, T. A. Rolim, and J. M. Formigli. "*GeDIg: Petrobras Corporate Program for Digital Integrated Field Management"* paper SPE 112153 presented at the 2008 SPE Intelligent Energy Conference and Exhibition held in Amsterdam, The Netherlands, 25–27 February 2008.