TRANSFORMING WATER INJECTION PROCESS WITH SMART AUTOMATION

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ABSTRACT

Employing water injection is a widely utilized method to sustain continual oil recovery from reservoirs. This involves maintaining reservoir pressure, managing the oil rim, and facilitating the movement of oil from injection wells to production wells. Given that many water injection facilities still heavily depend on manual operation, automating the injection process emerges as a crucial strategy.

The technical discussion begins by exploring typical water injection techniques, followed by an analysis of challenges and suboptimal operations in water injection processes within the company and industry. The subsequent focus is on the design of a fully automated water injection system, encompassing considerations such as equipment availability and constraints in aligning with well injection requirements. Petroboscan (Joint venture between Chevron and PDVSA in Venezuela) manage more than 40 water-injection wells but not all behave in the same way, being a problem commissioning the initial automation setup to improve the water injection in the field.

Although immediate adoption of process automation in mature assets may encounter obstacles such as system readiness, hardware availability, capital investment, and organizational mindset, the paper advocates for a phased approach. This involves implementing guided operations and semi-automatic procedures as initial steps towards eventual full automation deployment. By transitioning from manual to automated operation modes, the paper demonstrates improved responsiveness to process changes, leading to reduced instances of unplanned production deferment.

This involves implementing guided operation and semi-automatic operation as initial steps, preparing the ground for a comprehensive automation rollout. Shifting from manual reliance to automation enhances the response time to process changes, thereby reducing near-miss and trip incidents and minimizing unplanned deferments in production.

INTRODUCTION

The Boscan field boasts a substantial reservoir with an estimated 35 billion barrels of original oil in place (OOIP), comprising 10.5º API gravity asphaltic oil. Despite its vast potential, current production stands at just over 100,000 barrels of oil per day (BOPD), with a cumulative recovery factor of only about 5% OOIP after more than seven decades of operation. Traditionally, water flooding techniques were deemed ineffective for heavy oil fields like Boscan. However, a shift in strategy led to the successful implementation of water injection for pressure maintenance (WIPM), utilizing a unique pattern configuration and enhanced lifting capacity to capitalize on heightened reservoir pressure.

Initially, a four-pattern inverted seven-spot pilot and a combination of pattern configuration and line drive arrangement pilots were introduced in the central region of the field. The performance data from these WIPM pilots showed a localized increase in reservoir pressure, resulting in incremental secondary oil recovery. Building on this success and ongoing reservoir modeling, the WIPM projects are being expanded with a pseudo 1-3-1 inverted seven-spot pattern configuration, involving the addition of extra rows of producers between existing pattern rows.

The successful execution of Water Injection Pressure Maintenance Projects within the Boscan field has already yielded more than 75 million barrels of cumulative oil from secondary recovery, with another 270 million barrels of oil estimated to be recoverable to the Economic Limit. Reservoir simulation forecasts, validated using existing production data and analog forecasts, indicate the potential to recover an additional 52 million barrels of oil by 2026 (14 & 38 million barrels of oil respectively) and 189 million barrels of oil to the economic limit (59 & 130 million barrels of oil respectively).

Water injection process serves as a widely utilized secondary oil recovery method aimed at maximizing the extraction potential from oil reservoirs. When the reservoir pressure diminishes, resulting in decreased oil production during primary recovery stages due to a reduced pressure gradient between the reservoir and producer wells, water injection becomes instrumental. The process involves injecting water into the reservoir for two primary purposes: maintaining reservoir pressure and propelling oil from injection to production wells. In certain oil reservoirs, a combination of water and gas injection is employed to uphold the oil rim layer within the reservoir, ensuring alignment with the wellbore and optimizing oil production.

After being treated to remove any material that might interfere with its movement in the reservoir, water is injected through some of the wells in an oil field. It then moves through the formation, pushing oil toward the remaining production wells. The wells to be used for injecting water are usually located in a pattern that will best push oil toward the production wells. Water injection often increases oil recovery to twice that expected from primary means alone. Some oil reservoirs (the East Texas field, for example) are connected to large, active water reservoirs, or aquifers, in the same formation. In such cases it is necessary only to reinject water into the aquifer in order to help maintain reservoir pressure. Normally only 30% of the oil in a reservoir can be extracted, but water injection increases the recovery (known as the recovery factor) and maintains the production rate of a reservoir over a longer period.

Enhanced oil recovery (EOR) is designed to accelerate the production of oil from a well. Waterflooding, injecting water to increase the pressure of the reservoir, is one EOR method. Although waterflooding greatly increases recovery from a particular reservoir, it typically leaves up to one-third of the oil in place. Also, shallow reservoirs containing viscous oil do not respond well to waterflooding. Such difficulties have prompted the industry to seek enhanced methods of recovering crude oil supplies. Since many of these methods are directed toward oil that is left behind by water injection, they are often referred to as "tertiary recovery." The typical water injection process is shown in Figure 1.

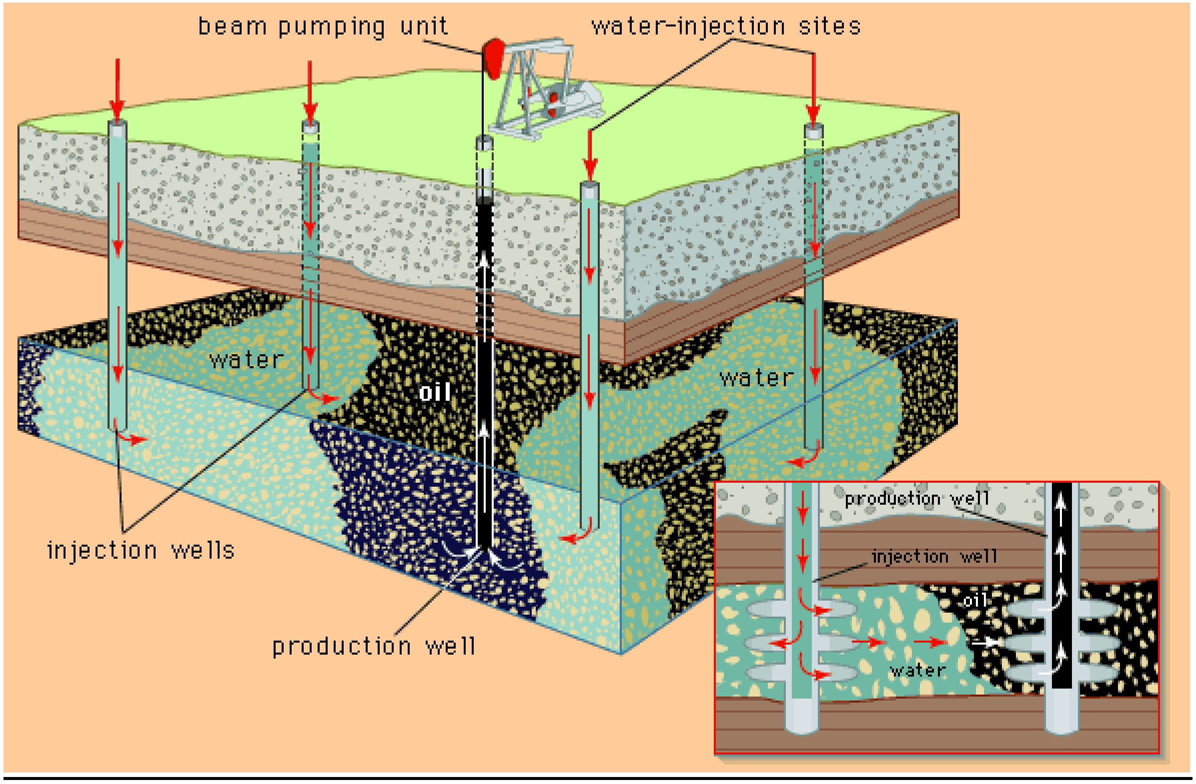

Figure 1: Typical Water Injection process.

PROBLEM STATEMENT

A poorly managed water injection process can lead to significant operational challenges, including detrimental effects on reservoir health and unplanned production deferment (UPD), ultimately impacting the long-term recoverable oil reserves. Additionally, operating the system below its design capacity can result in various issues such as corrosion and system trips. Addressing these challenges requires automation of the water injection system to account for additional constraints that may affect its operation.

Furthermore, process automation offers the opportunity to transition from manual to automated operation, enhancing efficiency and reliability. By integrating choke valves of injector wells with flowrate and pressure indicators, manual adjustments of injection rates can be automated. Similarly, in situations of reduced injection water supply, automation can allocate remaining water at a reduced rate to injector wells using pre-programmed logic or algorithms. Chemical injection skids can also benefit from automation to adjust chemical flow rates based on injection water flow rate.

The process control system hierarchy typically begins with field instrumentation, sensors, and analyzers to capture real-time process parameters. These inputs are then utilized in basic control schemes such as feedback and feedforward controls at the base layer control or regulatory control.

Modern water injection wells are typically designed to operate unattended for extended periods. Downtime means lost profits, so oil companies are willing to pay a premium for rugged, reliable equipment for their wellheads. Regular maintenance maximizes equipment lifetimes and allows impending problems to be dealt with proactively. But given its exposure to the elements, wellhead equipment can have problems even with regular maintenance. Until recently, most water injection wellheads were just equipped with basic pressure sensor alarms triggered when the outflow pressure dropped below a specific level.

In this specific case, Petroboscan managed more than forty water-injection wells but had problems commissioning their existing operational setup to improve and control the water injection on site. Typical installation in Boscan included a Lufkin SAM acting RTU. This device, which is an exceptionally good solution to control sucker rod pumping system, lacks process control capabilities. In the instrumentation set, there were also included an MC III EXP-flow totalizer-, a turbine meter and two pressure transmitters. The communication system consisted of a MDS Radio, charging system and a regular 12v sealed lead-acid battery.

The existing system presented the following problems:

1. Loss of setpoint (manually set) with every water plant’s shutdown, the operator journeyed to the well to correct the water injection rate.
2. The batteries were often stolen as a result, communication, and measurement.
3. Lufkin RTU is not robust enough, bugs and even snakes access the box damaging boards and connections.

Figure 2 shows the old setup we ought to review to provide a new design which has to be cheaper and simpler in terms of operation.

Figure 2: Water Injection well old automation setup.

This paper will delve into the design approach for a fully automated water injection system in Boscan oilfields.

OPERATIONAL SOLUTION

A reliable water injection module is critical to ensuring the health of the reservoir. One of the key process automation opportunities identified is integrating reservoir injection requirement with the system capacity and availability. Several possible configurations were identified which largely depends on instrumentation availability, complexity, and robustness of the resulting process control. In this specific brownfield project, the initial solution was built upon existing hardware and instrumentation to limit the CAPEX. The control strategy is designed to achieve the following objectives. In the development of these strategies, it is important that these are aligned with RWFM strategies in managing injection and with operations philosophy:

1. Maintain a stable water injection system based on supply and demand of water injection.
2. Allocate the water to wells based on reservoir target and wells' priority.
3. Maintain a stable WIM operation during transient and upset scenario.

The initial solution successfully worked in couple of wells, but it was complicated to roll it out due to water injection set point adjustment being done via operator's site visit.

A better solution was deployed adding a robust flow computer with control capabilities: Sensia QRate Scanner 3100. The new flow computer was the replacement of the MC III EXP and the Lufkin SAM controller. In order to control the choke based on the flow computer action, an electric actuator was installed. A lithium battery system embedded in the solar panel and a third pressure transmitter was added to the new instrumentation set, to help the water injection well optimization process.

Current process conditions required programming the flow computer in order to keep water being injected unless the difference between the flow line pressure (FLP) and tubing head pressure (THP) was equal to 150 psig.

One of the flow computer's key features is being pre-configured with a PID controller. The built-in universal PID controller maintains the flow, even if the conditions change. In this specific case, the QRate 3100 flow computer does perform FLP-THP subtraction and then assigns the result to the PID algorithm as a process value or PV. Indeed, the flow computer is capable to send to Petroboscan's SCADA system all process data: FLP, THP and CHP in addition to the choke valve state. Once the field system was tuned, the controller was able to operate the choke maintaining 120 psig between the FLP and THP. The operators were amazed with the simplicity and robustness of the system.

Since water slugs were also damaging the turbine meter internals, we will recommend the turbine meters with cone meters.

The new setup is shown in Figure 3.

Figure 3: Water Injection well new automation setup.

Another challenge was the integration to the SCADA system. Given some limitations in their SCADA host, a custom Modbus map was created then uploaded to the QRate 3100 flow computer. The host was able to successfully poll and change the set point remotely after this modification was added into the flow computer. Figure 4 shows the water injection well faceplate at SCADA side.

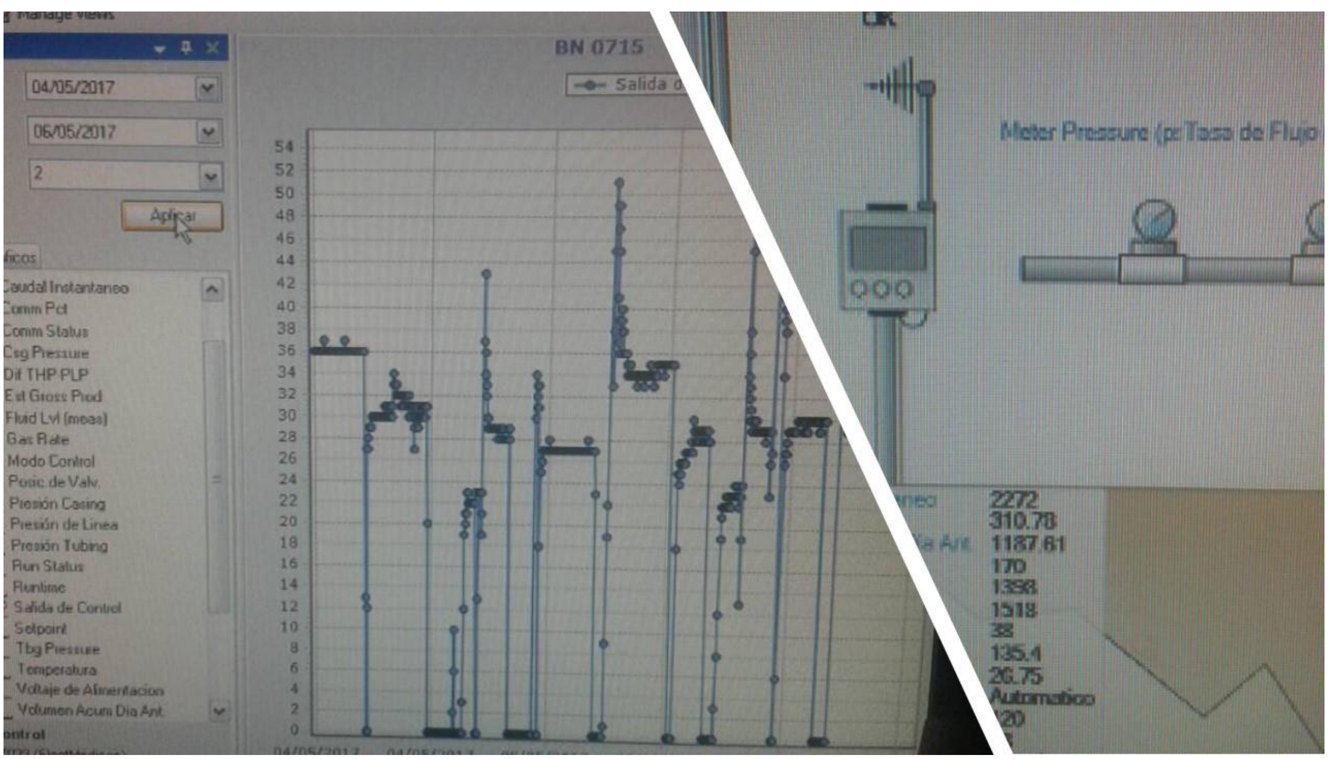

Figure 4. Water Injection wells SCADA faceplate

The new setup was fundamental to ensure stable water injection flow rates meet sub-surface requirements, automatically adjusting to any flow fluctuations. Finally, continuous monitoring, fine-tuning, and maintenance of the integrated control system -from the field level to the SCADA level- are essential to ensure its effective operation and optimization of the water injection facilities whilst preventing high-pressure conditions from reaching wells due to the QRate 3100 flow computer action in order to safeguard reservoir integrity.

CONCLUSIONS

The subsequent focus is on the design of a fully automated water injection system, encompassing considerations such as equipment availability and constraints in aligning with well injection requirements. Petroboscan (Joint venture between Chevron and PDVSA in Venezuela) managed more than 40 water-injection wells but not all behave in the same way, being a problem commissioning the controller to improve the water injection in the field.

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Water Injection process implemented in the Boscan field has generated an additional 77 MMBls of secondary oil production, which represents a 5% increase recovery factor.

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