WHOC14 - 321

Optimizing and Monitoring a Heavy Oil Reservoir using Progressive Cavities Pumps and Real Time Information in Dobokubi Field, Faja Petrolífera del Orinoco, Ayacucho Division - Venezuela

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ABSTRACT

Heavy oil reservoirs exploitation has increased during recent years; the economic viability by the increment in oil prices and the development and improvement of technology, has been influenced to explore and produce extensively the Faja Petrolífera del Orinoco reservoir, located in Venezuela. This reservoir represents the biggest reserve of heavy oil in the world, and at present, in its accountability, there are a proven reserves of 235 MMMB, and approximately 5000 wells.

The quantity of wells and facilities needed for such exploitation is related to a high investment in assets, and complex operations. In the Faja Petrolífera del Orinoco, in accordance to wells conditions, PCP is the artificial lift system commonly used and it is installed, in approximately 65% of the wells. Furthermore, a fully automate system, able to monitor and optimizes PCP wells automatically, can improve the company production operations, thus, its economic performance.

This paper discussed a case study of how real time information was managed as an intelligent process to be used to optimize well production and protect the PCP system and the reservoir. The system was able to calculate in real time,

well test results, and PCP and reservoir performance indicators. The time of processing is incomparable with a system no fully automatize or a manual process.

The system is formed by an intelligent processor located in the well location. And real time data goes into it, from: well's down-hole and surface sensors, and the VFD, to generate PCP wells diagnostic results in real time, to be delivered, to a user interface system, which can be located anywhere, to monitor and control the PCP wells. This architecture allows managing and monitoring in real time, objective reservoir flowing pressures to maximize reservoir productivity.

INTRODUCTION

The opportune diagnostic for optimization and the timely appliance of corrective actions in wells artificially lifted with progressive cavities pumps can increase asset run-life, optimize and maintain reservoir productivity, and maximize field production. The process of obtain calculated data for optimize and diagnosis a PCP well, can be complex and require a large period of time, if manual or semi-automatic process are applied.

To manually process the diagnostic and optimization procedure of a PCP well; the next steps should be cover:

- Schedule a well test to obtain total flow, water cut percentage and GOR.
- Schedule a pressure and temperature log to obtain the down-hole flowing pressure and temperature.
- Introduce, the well test and the pressure and temperature logs, in conjunction with the well completion, the artificial lift equipment characteristics, survey, IPR, and PVT data into a PCP well simulation software, and match the calculated well model with real well pressure measured points.
- If the well calculations can't be matched; the issue must be diagnosed to take the corrective action before the PCP fail.
- If the well is matched; run sensitivities on the simulation software for well production and PCP system optimization, assuring that optimization potential changes are inside of the PCP electrical and mechanical limits and reservoir limits.
- Prepare a work program for the field engineers and operators in the field to perform physical changes for the optimization or for correctives actions of the well operations.
- Schedule a new well test to assure the optimization or the corrective action was successful.
- Continue the process from the beginning recurrently in order to diagnosis and take actions opportunely, before the PCP well fails without detecting an operational problem.

Taking into account that those actions needs to be performed to a considerable number of wells in parallel, and continuously, a manual or a semi-automatic process will result in an cost ineffective field operations.

To maximize field production, PCP run-life and reservoir productivity and minimize operations expenses, an intelligent system was designed, which can perform the entire optimization and monitoring process in three automated steps, and in parallel in all wells belonged to an oil production field. Then, issues or changes, diagnosed in a PCP well, that merit performing physical changes for optimization, can be done right after is needed. Thus, the time of the process can be reduced as the minimum to maximize cost effectiveness of field operations.

The three steps, applying by this intelligent process, will be:

- Observing the well test results and the real time nodal analysis simulation on the system, and decide the bottom hole flowing pressure objective or the production target. Or directly observe if the PCP well is having an operational problem.
- The system automatically run the well model sensitivities and gives automatics recommendations, to field engineers and operators, and to users at the office, at the same time, for the optimization or to apply a corrective action.
- Perform the optimization or the corrective action, and monitor the results directly in the system. The processor will perform the same process minute by minute to adapt the well model to any real change within the reservoir and/or the PCP system.

In this paper, a real case study of the implementation of the above intelligent process will be discussed in details. Next paragraphs, will explain as topics the components and stages to implement this intelligent automated process. The topics are: Hardware, Software, Calibration, Operations, Advantages for Reservoir Monitoring, Case Study and Conclusions.

HARDWARE

The intelligent system is compound by: an intelligent processor with a touch screen panel, a communication device, and a wireless transmitter pressure and temperature sensor to sense at the production tubing at the well head, a GSM antenna, and antenna to receive the signal from the wireless sensor. (See figure number 1).

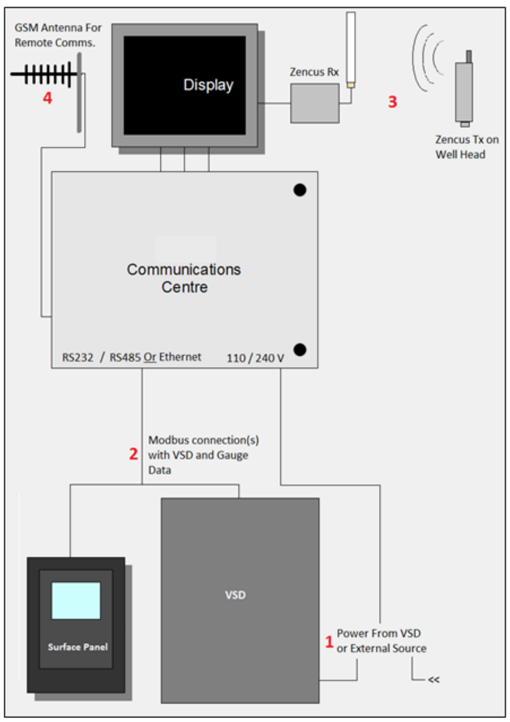

Figure 1. System Hardware Configuration.

The hardware excluding the WHP and WHT sensors is installed in a pedestal near to the VFD and the down-hole sensor panel. The intelligent processor receive the data from the VFD and the sensor panel using RS232 or RS 485 or Ethernet communications port located in the communication box device. Also, the processor receives through an antenna, the signal of the WHP and WHT sensors transmitted via wireless. After, the processor perform the calculations with the root data received, those are transmitted via GSM or SCADA to a server, and from the server the data goes to an interface user software where the data can be observed via internet, with the same format as at the well location. (See figure number 2).

Figure 2. System Architecture

SOFTWARE

The software inside the processor has the mathematics algorithms to calculate automatically and in real time using the data sense from the well sensors and the VFD, and the initial validated well model data, PCP´s diagnostic parameters as:

- Total flow
- Water Cut
- Bottom Hole Flowing Pressure
- Reservoir Drawdown
- Total GOR
- Estimate Productivity Index
- Free Gas at the Pump Intake
- Tubing Friction
- Dynamic Fluid Level
- Pump Volumetric Efficiency
- Motor & Rod Torque
- Additional Well Flow-rate
- Additional Well Drawdown

The system uses real time nodal analysis calculations, and PCP manufacturers pump curves to calculate the total flow. And the tubing multiphasic correlations, PVT data and WHP and WHT readings to calculate the water cut percentage and Total GOR.

The real time well test calculations feed the PCP well modeling, which is also, calculated in real time, for PCP well diagnosis and to identify if the equipment and the reservoir are inside the limits alarms.

If the bottom hole flowing pressure objective or the total flow objective is provided to the software, it is able to run a parallel optimization model to show automatically the opportunity to increase production, taking into account in the calculations, the PCP mechanical and electrical limits.

The signals from the well sensors (down-hole and surface), and VFD, are sensed and processed in conjunction with the well model data at the well location. And the engineers and operators at the field can observe the data using a touch screen panel (see figure number 3).

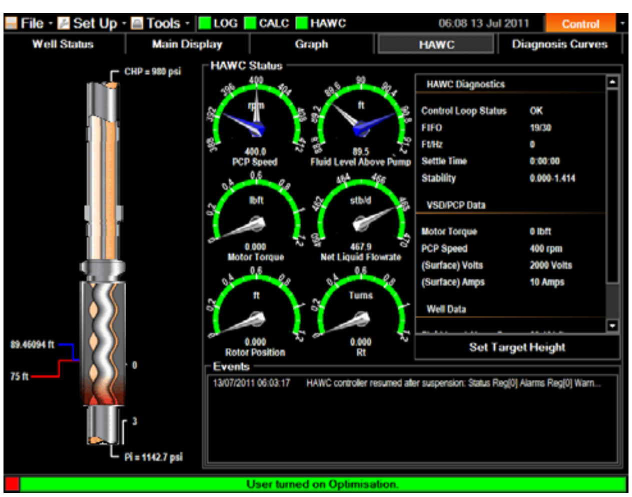

Figure 3.System Optimization Screen Showed on the Panel

The panel at the well location uses a dial and color system to show in a quick manner if the well is running without any operational issue. (See figure number 4).

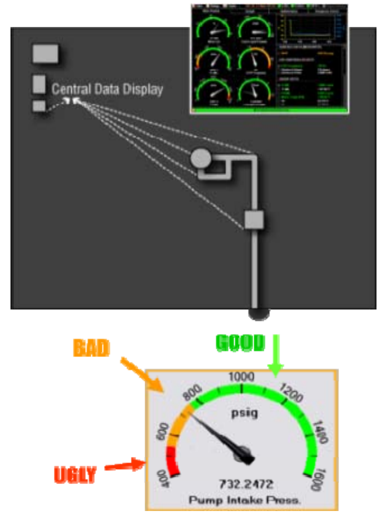

Figure 4. Dial Alarm System for Quick Well Inspection

After the calculations are made in the well location, all signals sensed and calculated parameters are sending in real time by GSM, security encrypted to a remote server, and from the server the data is sent to an interface user software, which can be accessed by internet. The data can be observed remotely by internet, exactly in the same format than in the panel at the well location. However, by internet the software can calculate values for the entire field as:

- Field Total Production.
- Field Total Production Optimization Available.
- Field Total Water Cut Percentage.
- Field Total Power Consumption.

Additionally the interface user software can generate automatically field and well reports, and send those via emails and/or SMS to users to alert them about any operational issue, and also can control the VFD for startup, turn off the PCP, and increase or decrease PCP´s frequency remotely. (See figure number 5).

Figure 5. Screen of the User Interface Software Showing Field Condensed Data

CALIBRATION

The system needs to be calibrated, by uploading an initial well modeling. For the processor, to be able to calculate data for well diagnosis, it must have inside the following validated parameters in comparison with the reality:

- Pump Manufacture
- Pump Diameter & Model
- Pump Depth
- Reservoir Depth
- Tubing Size
- Rod Size
- Casing Size
- Reservoir Pressure & Temperature
- Water Cut for IPR
- Productivity Index (PI)
- Oil Gravity
- Gas Gravity
- Solution & Free GOR
- Bubble Point Pressure
- Bubble Point Temperature
- Formation Volume Factor
- Oil Viscosity
- Oil Density
- Formation Water Density
- Total Liquid Flow Rate
- Water Cut
- Produced Water Density
- Wellhead Pressure & Temperature
- Pump Intake Pressure
- Pump Discharge Pressure
- Pump Intake Temperature
- Pump Discharge Temperature
- Drive RPM / Frequency
- Diluent injection rate

To validate the initial well model, to calibrate the processor; the parameters named above needs to be simulated in conjunction in a special designed software for well simulation. Basically, the gradients above the pump and below the will be constructed using the PVT data and the multiphase flow correlations, while, the differential pressure added by the PCP is calculated by using the manufacturers pump curves. After, of having a calculated well model, it is compared with the real measured points provided by the down-hole sensor (discharge, and intake pressure) for data validation.

When data is validated, and the calculated model match with the pressure points measured by the down-hole sensor, well test results calculations, will have an accuracy error less than 5%. Also, others diagnosis calculated parameters will have an high level of accuracy. (See figure number 6).

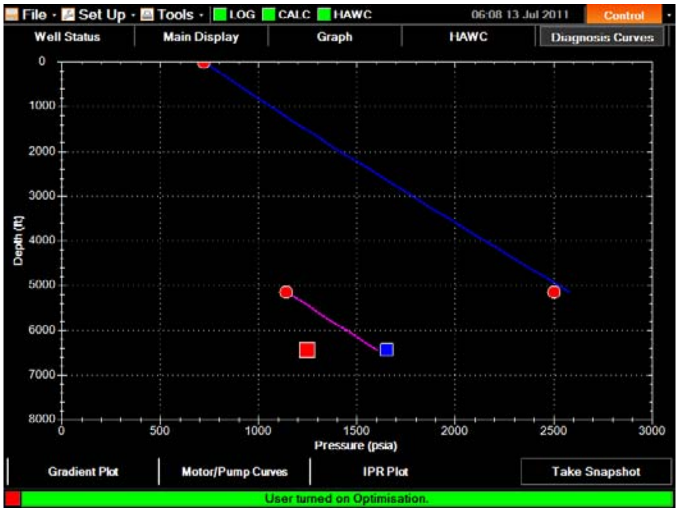

Figure 6. Initial system calibration; calculated gradients are correlated with the red points, which are the pressure measured points sensed by the gauges.

Figure 7. Screen of Well Status, Using a Color Code on a Map

OPERATIONS

After, the validated initial well model is uploaded into the processor, the processor is able to calculate the parameters for well diagnosis and well test results with high accuracy. The processor is able to calculate operational limits of the PCP automatically, because the PCP model is inside the initial model and the reservoir limit as the bottom hole flowing pressure objective must be provide for the reservoir or production engineers users, of the novel system.

The system is able to alarm the users by the system itself at the well location or by internet if any operational issue arise, but also, can send an email and/or an SMS to a cell phone.

The rate of the monitoring process is every minute, in each well and in parallel in all wells belonging to a field, condensed also every minute the field entire data, on the remote user interface software accessed through internet.

Also, the alarms for every sensed or calculated parameter into the system can be set manually at the well location or by internet. If the GSM communication is lost, engineers can have the calculated parameters at the well-site, and after the communication is reestablish the complete data will be pulled by the server to avoid lost critical well data.

The user interface software is able to show all wells in a map, using a color code to identify the current well status increasing efficiency of well operations. (See figure number 7).

For field operations management proposes the system can generate reports of wells functioning or field operations, which can be sending to email address, with an automatic periodicity, previously programed by the user.

The system can have control of the VFD remotely for startup, turnoff, increase and decrease frequency, for quick actions if it is needed. Also, the system provides management of data remotely; root sensors data and VFD data can be downloaded remotely or can be graphed on the system itself locally or remotely.

ADVANTAGES FOR RESERVOIR MONITORING

- Having the calculated data parameters named above and the well test results, every minute from different wells locations, belonging to a reservoir, all possible effects in production and in bottom hole flowing pressures can be monitoring with the system.

- Effects in the entire field, as for example: the introduction of new well into a reservoir, water injection wells as EOR, connectivity between wells, water cut increments vs. reservoir wells locations, etc. can be monitoring and study using the system.

- Also the system provide to accommodate bottom hole flowing pressure limit on each well belonging to a reservoir for parallel processing to have automatic optimization recommendations to take actions in real time for balance the production of the entire reservoir as an convenient matters, due to, for example: reduce or maintain water production, increase production in part of the field to keep production target when part of a field is on a shut-down, etc. (See figure number 8).

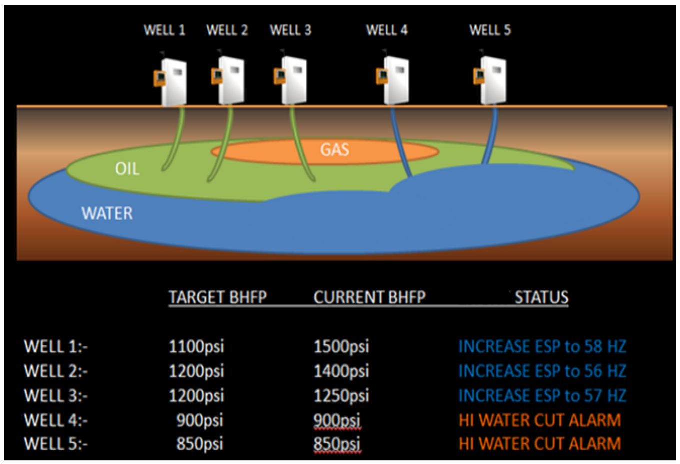

Figure 8. Example of Managing Production of a Water Drive Reservoir with the System.

CASE STUDY

The system was implemented in the well MFD-19, which belongs to Melones field, in the Faja Petrolífera del Orinoco in Venezuela.

Initially, production and reservoir engineers worked in conjunction with the system specialist to generate the validated initial well model to calibrate the processor.

After, the hardware was installed at the well site. The RS 485 Modbus address, from the sensor panel and the VFD was provided and programed into the processor and the signal and data was received and was verify for correctness. The WHP and the WHT signal was received through the receiver antenna and was verify the sensor calibration for correctness. Then, with the signals from sensors and the VFD, and the initial validated well model, the processor was able to generate accurate calculated data. (See figures, 9, 10, and 11)

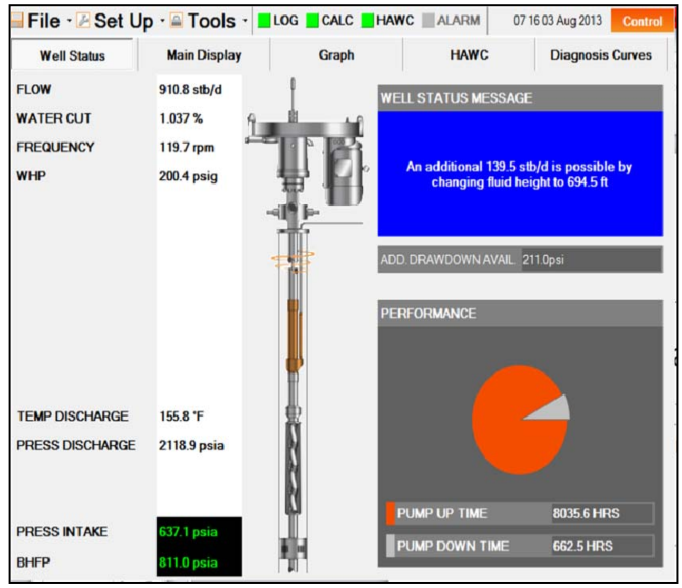

Figure 9. Screen of well status (MFD-19) showing initial flow calculations and the automatic well optimization recommendations, taking the fluid level of 694.5 as the production target.

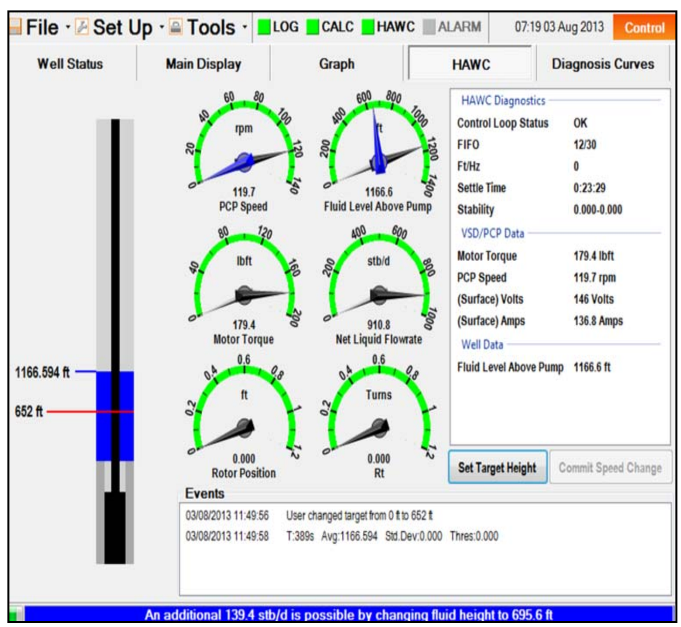

Figure 10. The optimization screen of well MFD-19, showing the optimization target and alarms in dials assuring the optimization will be inside the PCP limits.

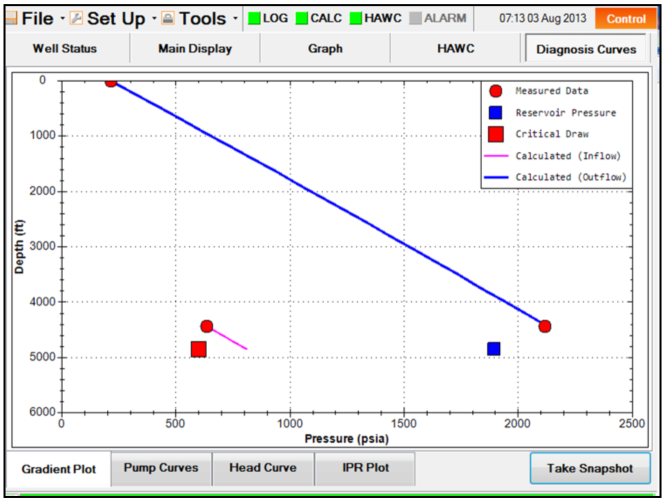

Figure 11. The automatic well modeling of well MFD-19 keeps the calculations correlated with the real measured points taken by the down-hole sensor, for quick problem identification.

The production and reservoir engineers were able to observe the real time constructed nodal analysis graph, and decide to introduce into the system a new limit of bottom hole flowing pressure, obtaining from the system the automatic recommendation for optimization. The frequency was increased for the new target, while the system monitored the PCP mechanical and electrical limits to alarm users. An increment of 110 BPPD was achieved. (See figure number 12)

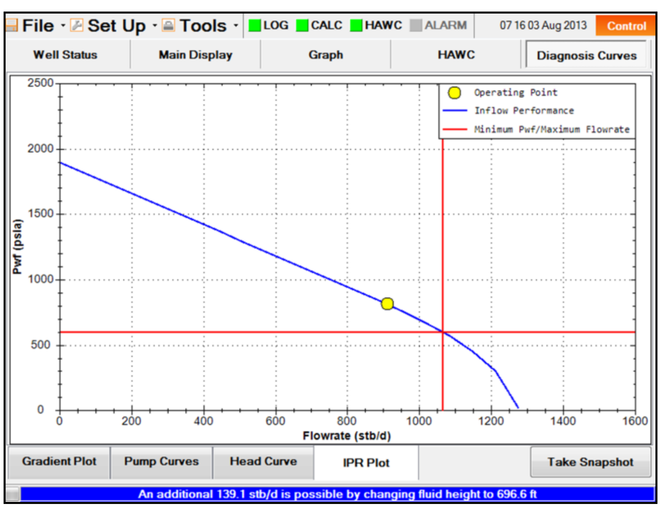

Figure 12. Screen with the real time nodal analysis construction (Well MFD-19), showing to the engineers users the real well potential for production optimization.

The well has a testing unit installed on location, to test the system, and the production after the optimization was compared and the accuracy error was of 2.1%. Also, PCP speed was varied to compare the well test results again the virtual calculation and the accuracy error was below 3% for all the speed changes.

Calculated data was easily accessed by the users at the well location using the touch screen panel. Software at the panel was positively tested by the users; data and diagnostics graphs such as the nodal analysis, the pump curve vs. operational point and the gradients plot was monitored to prove their veracity. (See figure number 13).

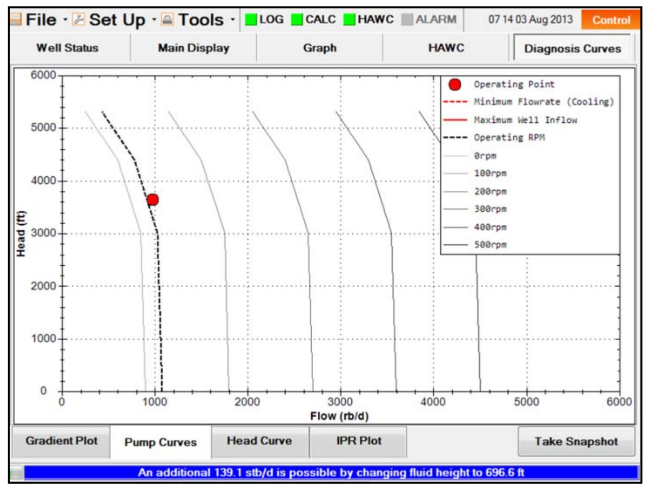

Figure 13. Pump Curve vs. PCP Operating Point (well MFD-19)

After the system was tested on location, the decision of install the remote server and observe the interface user software by internet was approved by the management. The data was send by a secure encrypted SCADA communications using a VPN address, to the server, and the data was accessed by internet by the users. The advantages of the remotely access, VFD control, data management, field map organization, well list by production priority organization, and reservoir production management was positively tested by the end users.

CONCLUSIONS

The implementation of the intelligent system, in a well belonging to the Faja Petrolífera del Orinoco proves the following premises:

- The system can reduce as maximum the time of well simulation for diagnose an operational issue or increase production in a well, maximizing field production and decreasing operational expenses.

- The system can be used to reduce the cost associated to the usage of mobile testing units in a high rate of periodicity for opportune well diagnosis.
- The system due to its capacity of process high quantity of data every minute, of each well and of the entire field, can be used to improved reservoir studies to increment the reservoir oil recovery factor.
- Due to its fully automatic processing, an alarm can be identified as soon as it happens, reducing as maximum the response time for corrective actions, increasing PCP run-life, improve reservoir productivity, and reduce as maximum the work-over rigs operations and its related cost.
- Due to its capacity of remote control and the availability also remotely, of root and analyzed data for startup, turnoff, and increase or reduce frequency safely, the system can reduce as maximum deferred production related to manually operations process.
- By implementing the system at the field level, the cost associated to QHSE, and manual operational process as mobilization can be reduced considerably.

ACKNOWLEDGEMENT

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NOMENCLATURE

BPPD: Barrels of petroleum per day.

GSM: Global system for mobile communications.

GOR: Gas oil ratio.

OIP: Oil in place

IPR: Inflow performance relationship.

PCP: Progressive cavity pump.

PVT: A shorthand term for pressure, volume, temperature dependencies for fluid properties.

QHSE: Quality, health, safety and environment.

VPN: Virtual private network.

VFD: Variable frequency drive.

SMS: Short message services.

WHP: Well head pressure.

WHT: Well head temperature.

SCADA: Supervisory Control And Data Acquisition