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Development of a graphical interface for simulating a gas lift system model using ScadaBR

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Abstract
The study of artificial oil elevation is essential in the oil industry to ensure satisfactory oil production in wells. One of the main artificial lift methods is gas lift, as it has low operating costs, and its principle guarantees good operation. The technology, being an integral part of the oil extraction process, requires a robust case study to optimize production efficiency throughout the life of the well. The integration of computerized simulations in the analysis of mechanisms speeds up the process of determining parameters, facilitating the project, and building solid premises for the construction of wells with a reasonable production rate and profitability to the operation. Therefore, this work aims to develop a graphical interface capable of creating a simulation and control environment for an oil well with a gas lift to bring reliability and robustness to sizing analyses, facilitating the ideal choice of the parameters of this process and for daily operation.

Keywords
gas lift; graphical interface; python; scadaBR

Introduction
The average operating time of an oil well is 30 years. Each oil reservoir has unique compositional attributes of the oil produced, which makes completion project unique.
Oil is extracted using the pressure difference between the reservoir and the top of the production tube. During well exploration, intensive monitoring is necessary. The parameters composition and reservoir pressure are essential for understanding the behavior of production flow, can change over time.
The expected behavior is that its composition will have less hydrocarbons and the pressure inside the reservoir will be lower. Therefore, the equipment installed in the well completion step must be sized to attend the requirements for ideal flow throughout the life of the well.
When the pressure difference between the reservoir and the wellhead is not enough for flowing, artificial lift methods must be implemented. Gas lift is an artificial lift method that injects high-pressure gas into the production column to reduce the pressure gradient between the reservoir and the wellhead [1].
Therefore, process simulation proves to be an important tool for defining the construction parameters of an oil well to obtain adequate sizing throughout the life of the well.
The main objective of this work is to create a graphical interface for controlling the oil flow process via gas lift. This interface aims to provide the user with a simple and reliable tool for sizing gas-lifted wells.

Methodology
The methodology is based on creating a graphical interface that can be operated with simulation data or real process data. Given the data communication method used, this alternate use is possible.
To build the interface, two flow models were used, described by Eikrem [2] and Ribeiro [3]. These mathematical models were implemented in Python. The interface be created using a SCADA system, which stands for Supervisory Control and Data Acquisition. A SCADA system efficiently provides real-time communication between the user and process variables [4].
Communication is necessary between the SCADA system to collect the data to be displayed, requiring a communication protocol. The protocol used is Modbus, which is widely used in the industrial automation sector and has a Python library.
In other words, the protocol allows the graphical interface to receive simulation data or real data without changing its construction.

ScadaBR graphical interface
ScadaBR is free, open-source software, which guarantees ease of implementation and use of the graphical interface. The software's tools include

visualizing variables, graphs, alarms, environments with supervisory screens and compatibility with various communication protocols.

Modbus protocol

The Modbus protocol is available in Python through the PyModbusTCP library, which has a master-slave access control mechanism, with the master sending read or write requests and receiving the response from the slave.

Eikrem's model for well production

The equations were described by [2] and are based on the following assumptions: Two-phase flow only oil and gas, ideal gas, without pressure loss in the flow and constant device temperature. The Equations (1), (2) and (3) describe the mass balance to the process.

$$\dot{z}_0 = w_{gc} - w_{iv} \quad (1)$$

$$\dot{z}_1 = w_{iv} - w_{pg} \quad (2)$$

$$\dot{z}_2 = w_r - w_{po} \quad (3)$$

Where $\dot{z}_0$ is the mass off gas in the annulus, $\dot{z}_1$ is the mass off gas In the Production tube, $\dot{z}_2$ is the mass of oil in production tube, w_{gc} is the flow gas injection in the annulus, w_{iv} is the flow gas from the annulus to production, w_{pg} is the gas flow in Choke valve, w_{po} is the oil flow in Choke valve and w_r is the oil flow from the reservoir to production.

The mass flows are described by Eq. (4), (5), (6), (7) and (8), which are determined from the pressure difference between the regions and the accumulation rates.

$$w_{iv} = C_{iv}\sqrt{\rho_{a,i}\max\{0, P_{ai} - P_{ti}\}} \quad (4)$$

$$w_{pc} = uC_{pc}\sqrt{\rho_m \max\{0, P_t - P_s\}} \quad (5)$$

$$w_{pg} = \frac{\dot{z}_1\, w_{pc}}{\dot{z}_1 + \dot{z}_2} \quad (6)$$

$$w_{po} = \frac{\dot{z}_2\, w_{pc}}{\dot{z}_1 + \dot{z}_2} \quad (7)$$

$$w_r = C_r\sqrt{\rho_o \max\{0, P_r - P_{tb}\}} \quad (8)$$

Where C_{iv} , C_r and C_{pc} are constants, $\rho_{a,i}$ is the density in annulus, ρ_m is the gas and oil mix density, ρ_o is the pure oil density, P_{ti} the pressure in tube injection,P_t is the tube pressure, P_r is the reservoir pressure, P_{ai} is the anular injection pressure, P_s is the manifold pressure, P_{tb} is the pressure at the bottom of the tube and u is a step function.

Equations (9) and (10) show the densities in different places and situations to the process.

$$\rho_{a,i} = \frac{M}{R\,T_a} P_{ai} \quad (9)$$

$$\rho_m = \frac{\dot{z}_1 + \dot{z}_2}{L_t\, A_t} \quad (10)$$

Where R is the universal constant of gas, T_a is the anulus temperature, M is the molar mass of gas, L_t is the tube length and A_t is the tube area above the injection.

Equations (11), (12), (13) and (14) show the pressures, which are determined from the hydrostatic and thermodynamic plots.

$$P_{ai} = \dot{z}_0\left(\frac{R\,T_a}{V_a M} + \frac{g\,L_a}{V_a}\right) \quad (11)$$

$$P_t = \frac{R\,T_t\,\dot{z}_1}{M\,(L_t\,A_t - V_o\,\dot{z}_2)} \quad (12)$$

$$P_{ti} = P_t + \frac{g\,(\dot{z}_1 + \dot{z}_2)}{A_t} \quad (13)$$

$$P_{tb} = P_{ti} + \rho_o\, g\, L_r \quad (14)$$

Where T_t is the tube temperature,V_a is the annulus volume, L_r is the distance between tube bottom and annulus injection, L_a is the annulus length, A_r is the tube area below annulus injection, g is the gravity acceleration and V_o is the specific volume of oil.

Ribeiro's modified model

The model is based on [3] model, with the same considerations, however, it includes the loss of pressure during flow.

Equations (15), (16), (17), (18) and (19) show the pressures with the correction factor considering the pressure loss. The equations also depend on the fluid flow regime, whether laminar or turbulent.

$$P_{ti} = P_t + \frac{g\,(\dot{z}_1 + \dot{z}_2)}{A_t} + \frac{f_a\,\rho_m v^2}{2D} \quad (15)$$

$$P_{tb} = P_{ti} + \rho_o\, g\, L_r + \frac{f_a\,\rho_m v^2}{2D} \quad (16)$$

$$f_a = \frac{64}{Re} \quad (17)$$

$$f_a = 0{,}316\,.\,Re^{-0{,}25}, se\ Re < 50000 \quad (18)$$

$$f_a = 0{,}184\,.\,Re^{-0{,}20}, se\ Re > 50000 \quad (19)$$

Where μ is the dynamic viscosity.

Results and Discussion

The interface has three environments, which provide different information to the user. Figs. 1, 2 and 3 show the environments, which have specific functionalities.

The left side is equal in all the three screens. It has navigation buttons, variable commands, and alarms. The navigation buttons allow you to switch between different screens, the variable command buttons allow the user to define and change the simulation parameters.

The variables available for manipulation are: ρ_o , P_r, T_a, w_{gc}, P_s, T_t, choke valve, gas lift valve and reservoir valve opening. The on/off button for the simulation and the keep history box. The keep history box allows the user pause and return to the simulation without the parameters being restarted.

The alarm box shows five different message options: information, urgent, critical and life safety. General program information appears as information and the most critical alarms can be defined by the user depending on the operation Figure 1 shows the variables in an expanded form. These variables appear on the three screens.

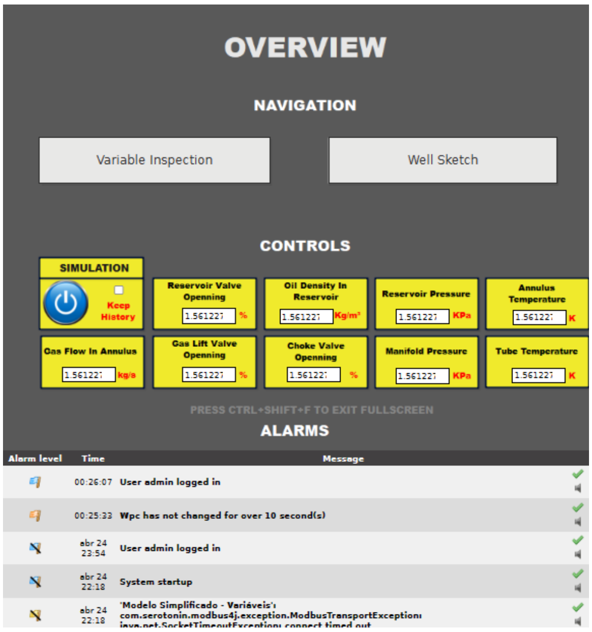

Figure 1. Screen control and navigation area.

Figure 2 shows real-time flow and pressure everywhere in the production pipe. The locations are described by: Reservoir, production tube, annulus and wellhead. Variables have colors and symbols for ease of user viewing.

The variables in red indicate the pressures, in blue the densities, and in black the flow rates. The pointers indicate the opening of the valves, and the horizontal bars below the pointers are for controlling the opening of these valves.

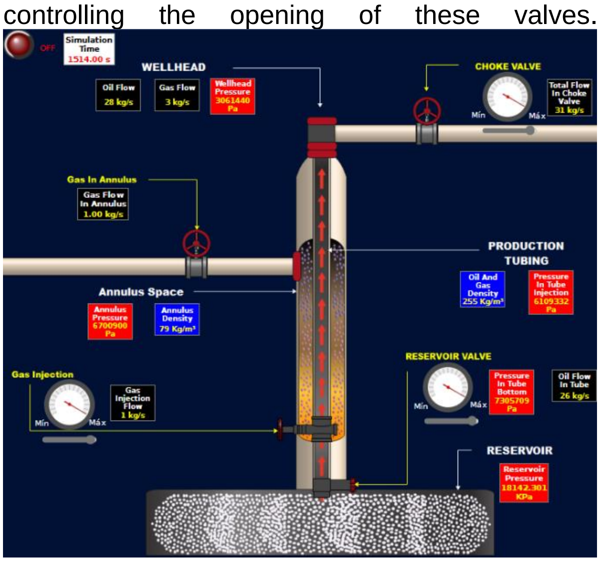

Figure 2. Overview screen.

Figure 3 shows the behavior over time of the following process variables: P_{ai}, P_t, P_{ti}, P_{tb}, w_{iv}, w_{pc}, w_{pg}, w_{po}, w_r, $\rho_{a,i}$ and ρ_m. This screen is important to check the behavior over time and the behavior after a disturbance. The user may identify whether steady state has been reached from the graphics. The graphs show the process variables determined over a period of one hour, but this can be configured by the user in the software.

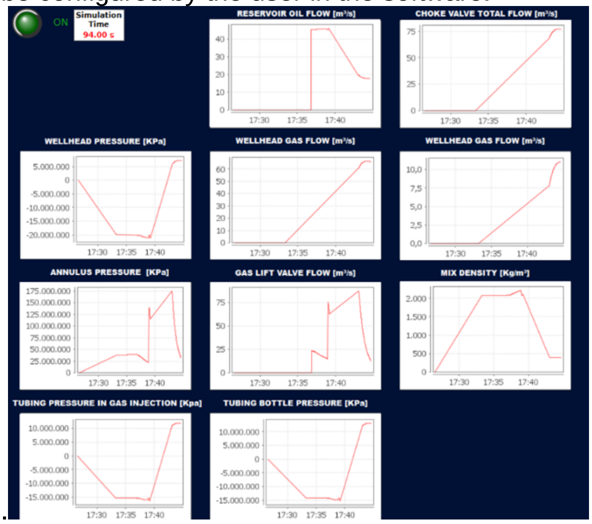

Figure 3. Variable Inspection screen.

Figure 4 shows the well sketch. The user can configure the construction parameters for implementing models c and c as necessary. It is possible to configure the length and diameter of the tube above and below the gas injection point, the length and diameter of the annulus, the distance between the gas injection valve and the reservoir and the molar mass of the injected gas.

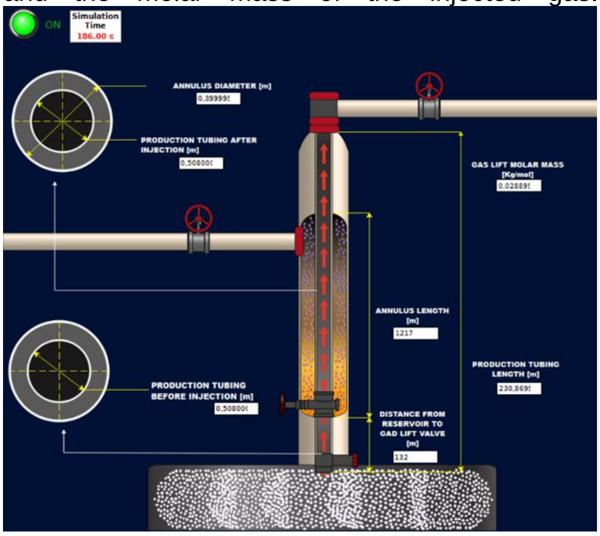

Figure 4. Well Sketch screen.

To communicate the model with the graphical interface, ModbusTCP was used. This protocol is operated from servers for reading and writing communication. This server was developed in Python and uses a specific port.

Within the code containing the mathematical flow model, it was necessary to create reading and writing functions, so that it receives the inputs from the graphical interface and returns the outputs at each iteration, standardized in 1 second.

The reading and writing methodology used in the simplified and modified model is identical. The codes containing the models implemented with the protocol increment, the communication server, and the code of the ScadaBR graphical interface are available at https://github.com/m0dest0/GasLiftGraphicalInterface.

Conclusions

The graphical interface was successfully innovated in the ScadaBR software, achieving satisfactory communication with the Python mathematical model through the Modbus server.

However, it is necessary to previously execute the codes in a Python interface for subsequent manipulation and control within the ScadaBR software.

The ModbusTCP allows the graphical interface to receive data from Python simulation models or real data from sensors without changing the communication method.

The interface facilitates the user's simulation experience by making it easier to simulate and adjust model parameters.

References

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