Project DATA

Well model consists of 5 free variables and 24 calculated variables(columns) in TPD-file(.txt file)

Free variables(5)

- Rates (liquid rate) =20 values
- Gaslift injection rate(V4) = 7 values
- WC(V3)=12 values
- GOR (V2)= 10 values
- Top node pressure(V1) is BHP = 10 values

→ 168,000 row values for calculated variables

```
# Rate Values
314.491, 400.747, 510.662, 650.724, 829.202, 1056.63, 1346.44, 1715.73, 2186.32, 2785.97, 3550.09, 4523.79, 5764.55, 7345.62, 9360.34, 11927.6, 15199.1, 19367.8, 24679.9, 31449
# Variable 4 (Gaslift Gas Injection Rate) values
0, 0.354937, 0.709875, 1.41975, 2.48456, 3.54937, 4.96912
# Variable 3 (Water Cut) values
0, 5, 10, 20, 30, 40, 50, 60, 70, 80, 90, 99
# Variable 2 (Gas Oil Ratio) values
507.901, 598.194, 722.912, 1128.67, 1693, 2821.67, 4232.51, 5643.34, 7054.18, 8465.01
# Variable 1 (Top Node Pressure) values
1725.76, 1814.39, 1903.03, 1991.66, 2080.29, 2168.93, 2257.56, 2346.2, 2434.83, 2523.46
```

Calculated variable(24)

Which is 2 first column in

.txt file and here

Only firs column named

WHP is important

- Flowing BH p
- WH T
- Inject depth
- Top node depth
- Valve tubing & casing P/T
- Gas inj rate
- Gaslift gas gravity
- P/T & mix velocity
- Erosion /corrosion rate

WHP

```
# 4 Variable TPD Results
       16.0553,        40.7451,
        33.294,        42.0333,
       54.8966,         43.861,
       80.5033,         46.451,
       109.629,        49.9886,
       141.726,        54.6728,
       176.104,        60.6817,
       211.882,        68.1043,
       247.945,        76.8677,
       282.637,        86.7056,
       315.415,        97.1932,
       342.141,        107.834,
       362.546,        118.158,
       375.303,        127.789,
       379.375,        136.482,
       375.267,        144.115,
       363.691,        150.666,
       340.618,        156.188,
       298.003,        160.773,
       212.752,        164.535,
       189.759,        41.6613,
       200.463,        43.1096,
       213.121,        45.0606,
        228.01,        47.7439,
       245.236,        51.3432,
        264.77,        56.0531,
       286.381,        62.0427,
       309.571,        69.3927,
       333.562,         78.031,
       357.342,        87.7038,
       378.306,        98.0075,
       394.719,        108.468,
       405.795,        118.631,
       410.191,         128.13,
       406.899,         136.72,
       396.633,        144.277,
       380.051,        150.774,
        352.93,        156.259,
       306.871,        160.819,
       218.569,        164.565,
       312.918,        42.7008,
       319.084,        44.2672,
        326.44,         46.311,
       335.273,        49.0656,
       345.705,        52.7103,
        357.76,        57.4331,
```

Fun is the objective function

Two types of constraints exist here: → $c(x) = 0$ or $c(x) \geq 0$

Optimization has a function →

$$\begin{aligned} \min \quad & f(x) \\ \text{subject to} \quad & g(x) = 0 \\ & h(x) \leq 0 \end{aligned}$$

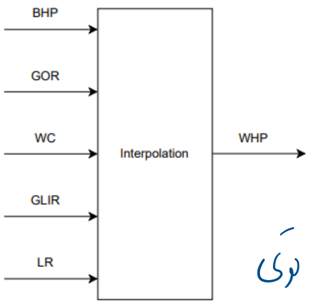
constraints

objective function

$$\min_{x \in \mathbb{R}^n} f(x) \quad \text{subject to} \quad \begin{cases} c_i(x) = 0, & i \in \mathcal{E} \\ c_i(x) \geq 0, & i \in \mathcal{I} \end{cases}$$

Interpolation

Due to having discrete points instead of continuous interpolation is required for the free variables. interpolating all free variables gives only one variable WHP



$\theta = (\mathrm{BHP}, \mathrm{GOR}, \mathrm{WC}, \mathrm{GLIR}, \mathrm{LR})$

$y = g(x, \theta)$

→ WHP (weelhead pressure)

θ has constant values but in 3 optimization problems below some values θ are variable

برای interpolation داریم با 5 تا free variable ها مقدار WHP توی
ستون اول رو بدست بیاره

Convert points : alpha beta and landa have different values for 5 free variables

$$\mathrm{res} = (x + \alpha) \cdot \beta + \gamma$$

- Rate values: BBL/day to m^3/day: $\alpha = 0,\ \beta = 0.159,\ \gamma = 0$
- Gas lift rate: MMSCF/day to m^3/day: $\alpha = 0,\ \beta = 28173.974,\ \gamma = 0$
- WC: No convertion done
- GOR: SCF/STB to Sm^3/Sm^3: $\alpha = 0,\ \beta = 0.178,\ \gamma = 0$
- Pressure: PSI to bar: $\alpha = 0,\ \beta = 0.069,\ \gamma = 1$

- Column number 0 (WHP): PSI to bar: $\alpha = 0,\ \beta = 0.069,\ \gamma = 1$
- Column number 1 (WHT): °F to °C: $\alpha = -32,\ \beta = 0.556,\ \gamma = 0$

where the constants α, β and γ are inputs to the method decided by the list in ”dict conversion”.

Optimization

With method slsqp did optimization for 3 cases(there is not any Opt2)

1. minimize gas lift injection rate with constraints to min WHP
2. Minimize more complex objective function for one well
3. Minimize more complex objective function for multiple wells

#Opt1 : Minimize Gas Lift Injection Rate

x is Gas lift injection rate

$$\min_{\{x\}} \quad f(x) \rightarrow \text{objective function} \Rightarrow f(x) = x \rightarrow \text{Gas lift injection}$$

$$\text{s.t.} \quad c(x) \geq 0 \longrightarrow \text{constraints} \longrightarrow c(x) = g(x, \theta) - y_{min}$$

Always ≥ 0

$$\text{where } lb \leq x \leq ub$$

bounds (lower and upper bounds)

با free variable ها، interpolation انجام میدن ~
مقدار فشار رو که توی ستون اول (WHP)

input value $\theta = (\mathrm{BHP}, \mathrm{GOR}, \mathrm{WC}, x, \mathrm{LR})$

python → res = interpol (input value)

where x is the gas lift injection rate, $f(x) = 1 * x$ and $c(x) = g(x, \theta) - y_{min}$ where $\theta = (\text{BHP}, \text{GOR}, \text{WC}, x, \text{LR})$ as described in section 3.4. y_{min} is the minimum required WHP and lb and ub are lower- and upper bounds.

#Opt3 : Minimize More Complex Objective Function for One Well

opt هدف

1) تفاوت $\underbrace{\text{Oil Rate}}_{x_0}$ و $\underbrace{\text{Oil Rate target}}_{\alpha}$ کمینه شود

2) تفاوت $\underbrace{\text{Gas lift}}_{x_1}$ و $\underbrace{\text{Gas lift target}}_{\beta}$

ست کمینه برای یک چاه

x is both Oil Rate and Gas lift inj Rate →

$$\min_{\{x\}} \quad f(x)$$

$$\text{s.t.} \quad c(x) \geq 0 \longrightarrow C(x) = g(x, \theta) - \underbrace{Y_{min}}_{20\,(WHP)}$$

$$\text{where } lb \leq x \leq ub$$

$$\text{where } x = [x_0,\ x_1] = [\text{OR},\ \text{GLIR}]$$

objective function

oil rate target

$$f(x) = \omega_1 * (x_0 - \alpha)^2 + \omega_2 * (x_1 - \beta)^2$$

ω_1 ω_2 weight = Constant

Gas Rate target

$\alpha = OR_{target}$ and $\beta = GLR_{target}$. $c(x)$ is the same as in 3.6.1, but θ is different due to two variables instead of one:

w_2 & w_1

$$\theta = (BHP, GOR, WC, x_1, LR) \longrightarrow$$

θ اینجا 2 تا متغیر داره X_1 و LR هر دو تغییر پذیر هستند

$$\text{where } LR = \frac{x_0}{1 - \frac{WC}{100}}$$

	lb	ub
OR =	[375,	1899]
GLIR =	[25000,	110000]

#Opt4 : Minimize More Complex Objective Function for Multiple Wells

(اصل همون opt3 هست ولی برای چندتا چاه)
تفاوتش فقط توی objective funct و constraint هست

$$\min_{\{x\}} \quad f(x)$$
$$\text{s.t.} \quad c_1(x) \geq 0$$
$$c_2(x) \leq \text{GLR Total}_{max}$$
$$\text{where } lb \leq x \leq ub$$
$$\text{where } x = [x_0,\, x_1,\, ...,\, x_{n\cdot 2},\, x_{n\cdot 2+1}] = [OR_0,\, GLR_0,\, ...,\, OR_n,\, GLR_n]$$

$$f(x) = \sum_{i=0}^{i=N-1} \omega 1_i \cdot (OR_i - \alpha_i)^2 + \omega 2_i \cdot (GLR_i - \beta_i)^2$$

→ obj function / α, β oil target – Gas injection target

constraints

$$c_1(x) = [c1_1(x), c1_2(x), ..., c1_N(x)]$$
$$c1_i(x) = g(x, \theta_i) - y_{min_i}$$
$$\text{where } \theta_i = (\text{BHP}_i, \text{GOR}_i, \text{WC}_i, x_{2\cdot i+1}, \text{LR}_i)$$
$$\text{where } LR_i = \frac{x_{2\cdot i}}{1 - \frac{WC_i}{100}}$$

} $C_1 \rightarrow$ Pressure

$$c_2(x) = \sum_{i=1}^{i=n} x_{(2\cdot i-1)}$$

} $\rightarrow C_2 \rightarrow$ GLIR

توی opt1 و opt3 فقط Constraints مربوط بود به فشار WHP

ولی در opt4 تو حالت داره Constraints

1) Constraints روی فشار (WHP) (C_1)

2) Constraints روی مقدار کل Gas injection (C_2)

$C_1 \rightarrow C_1(x) \geq 0$

فشارها تو opt3 هست

ولی برای چاه‌ها

$$\begin{cases} C_1(x) = [cl_1(x), cl_2(x), \ldots] \\ cl_i(x) = g(x, \theta_i) - \frac{y_{min}}{20} \\ \theta_i = (BHP_i, GOR_i, WC_i, x_{2,i+1}, LR_i) \\ LR_i = \frac{x_{2i}}{1 - \frac{WC_i}{100}} \end{cases}$$

مقدار این از interpolation بدست می‌یاد

Gas lift به صورت گرد شده

water cut همون WCi

از اینجا می‌گم ثابت هستند به غیر از

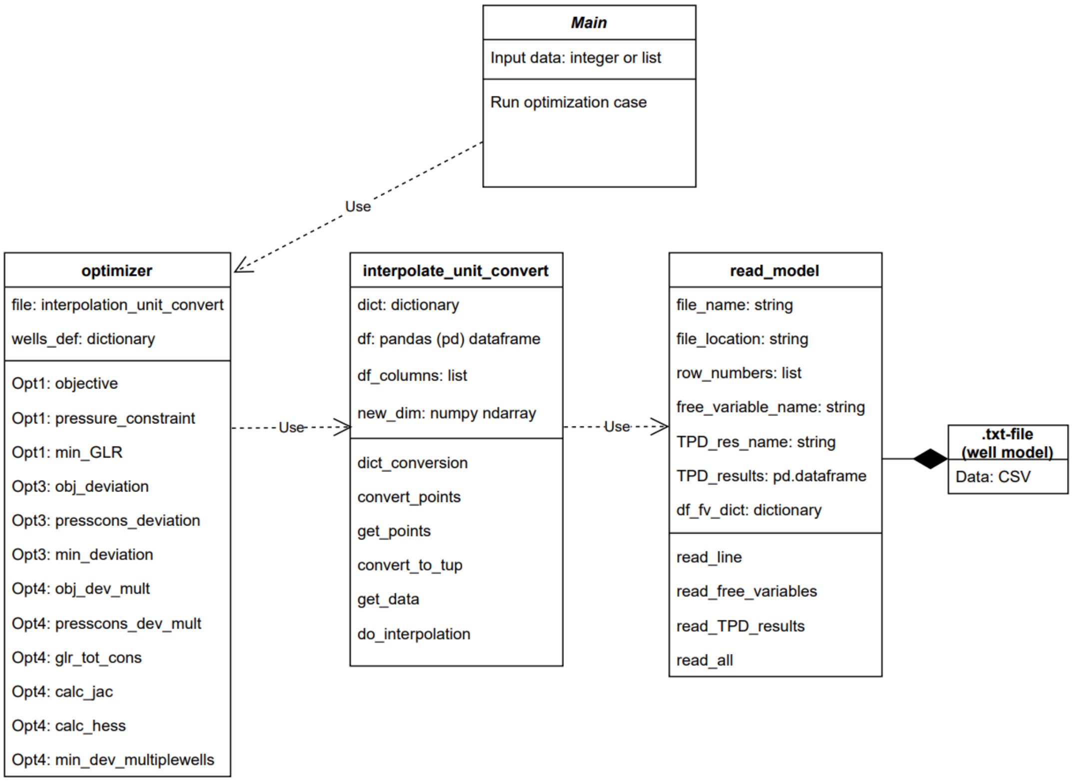
ω_1 و ω_2 هم ثابت هستند

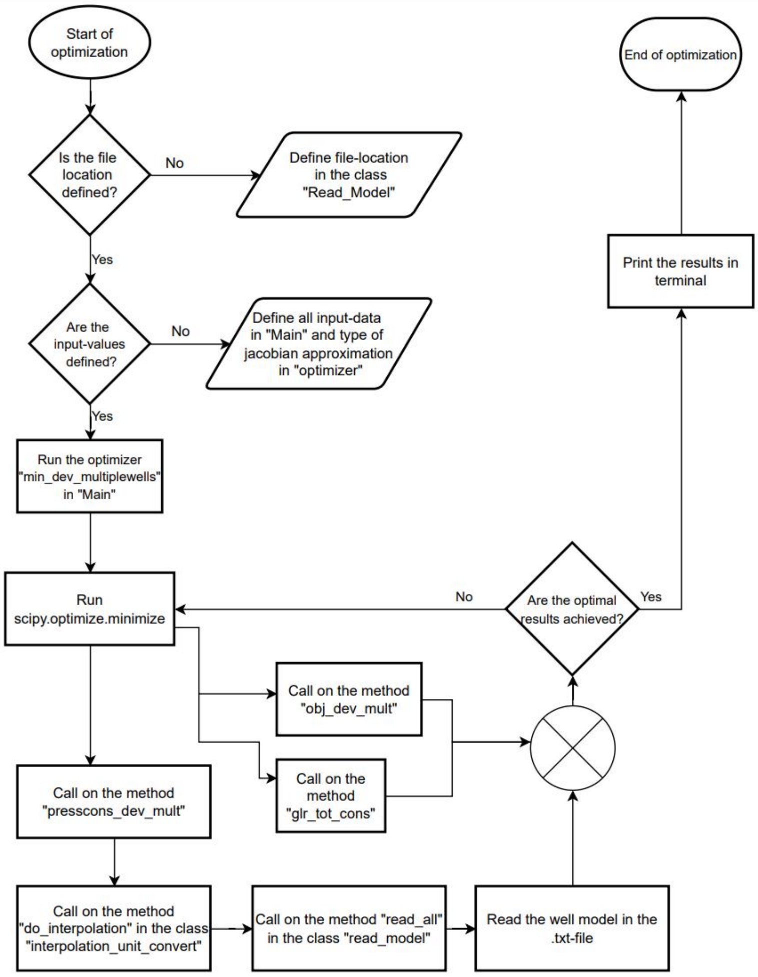
$C_2(x) \leq GLR\ total$

$$C_2(x) = \underbrace{\sum Gas}_{\text{جمع}} = \sum \frac{x_{2i+1}}{\text{فرد}} \leq GL\_max$$

گاز فرد

$x = [x_0, x_1, \ldots x_{2n}, x_{2n+1}]$


Main
Input data: integer or list
Run optimization case
Use
optimizer
file: interpolation_unit_convert
wells_def: dictionary
Opt1: objective
Opt1: pressure_constraint
Opt1: min_GLR
Opt3: obj_deviation
Opt3: presscons_deviation
Opt3: min_deviation
Opt4: obj_dev_mult
Opt4: presscons_dev_mult
Opt4: glr_tot_cons
Opt4: calc_jac
Opt4: calc_hess
Opt4: min_dev_multiplewells
Use
interpolate_unit_convert
dict: dictionary
df: pandas (pd) dataframe
df_columns: list
new_dim: numpy ndarray
dict_conversion
convert_points
get_points
convert_to_tup
get_data
do_interpolation
Use
read_model
file_name: string
file_location: string
row_numbers: list
free_variable_name: string
TPD_res_name: string
TPD_results: pd.dataframe
df_fv_dict: dictionary
read_line
read_free_variables
read_TPD_results
read_all
.txt-file
(well model)
Data: CSV


Start of optimization
Is the file location defined?
No
Define file-location in the class "Read_Model"
Yes
Are the input-values defined?
No
Define all input-data in "Main" and type of jacobian approximation in "optimizer"
Yes
Run the optimizer "min_dev_multiplewells" in "Main"
Run scipy.optimize.minimize
Call on the method "obj_dev_mult"
Call on the method "glr_tot_cons"
Call on the method "presscons_dev_mult"
Call on the method "do_interpolation" in the class "interpolation_unit_convert"
Call on the method "read_all" in the class "read_model"
Read the well model in the .txt-file
Are the optimal results achieved?
No
Yes
Print the results in terminal
End of optimization

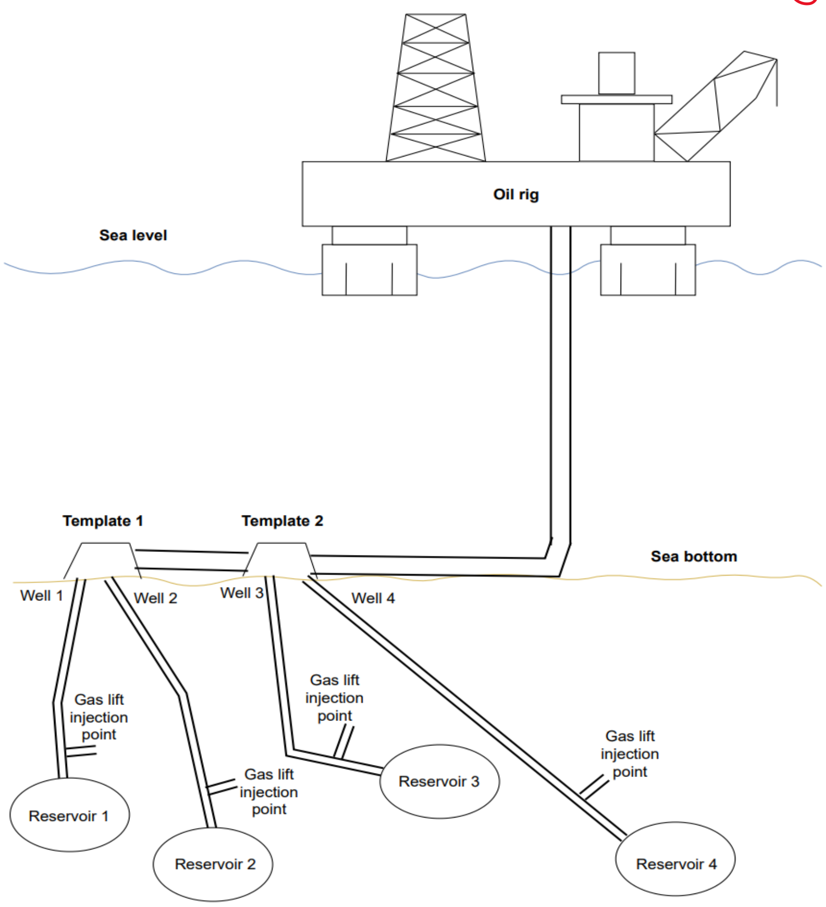
entire works he did in this project except GUI ,I should do

- Read the model-file into Python
  - For this project it is a .TPD file, but the reading should be modular so it can have different models as input
  - The importing has to account for that the number of free and calculated variables can vary
- Interpolate the table
- Make a code that calculate the derivatives of the interpolated table (or use existing Python-packages)
- Solve gas lift optimization using Python algorithms (scipy.optimize)
  - Solve two optimization problems for one well
  - Solve one optimization proble for multiple wells, returning optimized production- and gas lift injection rates for each well to minimize the objective function.
  - Test different methods against each other with respect to convergence and running time
- Make a simple graphical user interfaceGUI to manage the optimization-case:

Gui

1. Specify wells with belonging Prosper-file
2. Specify bounds and constraints
3. Specify type of optimization-algorithm
4. Start/stop optimization
5. Plot results

Gas lift inj Rate Process



GLIR :gas lift injection rate

Aim of this project is maximize oil rate with constraints for pressure(WHP) and GLIR