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Sudan University of Science & Technology

College of Petroleum & Mining Engineering

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Production optimization using surface network modeling

(Case study: Hamra oil field - Sudan)

تحسين الإنتاج بإستخدام نمذجة شبكة الإنتاج السطحية

دراسه حالة : حقل حمرة النفطي – السودان

This dissertation is submitted as a partial requirement of B.Sc. degree (honor) in petroleum and natural gas engineering

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Nov 2020

الإستهلال


اقرأ باسم ربك الذي خلق
خلق الإنسان من علق
اقرأ وربك الأكرم الذي
علم بالقلم علم الإنسان ما لم يعلم
١٤٢١

Dedication

We would like to donate this unpretentious effort to:

Our Parents;
Whom have endless presence and for the never ending love and encouragement.

Our brothers and sisters;
Whom sustained us in our life and still.

Our teachers;
Whom lighted candle in our ways and provided us with light of knowledge.

Senior Industry researchers and engineers.

Finally;
Our best friends and Classmates to their support and encouragement.

Acknowledgements

Thanking to Allah before and after...

First and foremost; we would like to express our sincere gratitude to our teachers for their undetermined support.

Special thanks to Mr. **Mohanned Mahjob Khairy** for his assistance, guidance and monitoring whenever needed…

Also we would also like to extend our appreciation toward OEPA production engineers for their support regarding obtaining the data required to complete this project.

This thesis is the end of our journey in obtaining our B.Sc. degree in petroleum engineering; through this journey we were grateful to be a part of department of petroleum engineering, so we take this opportunity to thank all members and workers at College of Petroleum & Mining Engineering for their facilitation and cooperation...

Eventually, we wish to express our sincere gratitude to our colleagues and families for their encouragement and moral support.

ABSTRACT

Most of the Sudanese fields face the challenges of maintaining production rates, which are decreasing at a large rate annually. This project aims to find a solution that helps to improve the production rates in Hamra Field by identifying the possible causes and factors influencing them using the developed model to maintain long production stability.

The main design of wells and jointing them with a specific network play an effective role in especially in primary recovery stage of oil production.

Otherwise in next stages of recovery attention is more focused on more issues such as insurance of no constrains in the production system as well as de-bottlenecking and back pressure, pressure and temperature distribution, flowing liquid viscosity analysis, error in wellhead pressure, Adding generic transfer pump, analysis of high water cut issue and mainly observe production status to take the right decision in it proper time, these all preventing from the production stability inhibition with time.

The main aim of study is design a Network model to analyze field data and to find ideal conditions and optimal production that can be achieved under current operational conditions and available equipment and thus help to make a proper decision and future planning for field development.

Keywords: production optimization, production stabilization, network modeling, Network diagnosing, production status observation, excess water diagnosing.

التجريد

تواجه معظم الحقول السودانية تحديات الحفاظ على معدلات الإنتاج الخاصة بها والتي تتناقص بمعدل كبير سنويًا. يهدف هذا المشروع إلى إيجاد حل يساعد على تحسين معدلات الإنتاج في حقل (حمرا) من خلال تحديد الأسباب والعوامل المحتملة التي تؤثر عليها باستخدام النموذج المطور للحفاظ على استقرار الإنتاج على المدى الطويل.

التصميم الرئيسي للآبار وربطها بشبكة معينة يلعب دورًا فعالًا في مرحلة الاسترداد الأولية لإنتاج النفط بشكل خاص.

بخلاف ذلك ، في المراحل التالية من الاسترداد ، يتم التركيز بشكل أكبر على المزيد من القضايا مثل التأكد من عدم وجود قيود في نظام الإنتاج وكذلك إزالة الاختناق والضغط العكسي وتوزيع الضغط ودرجة الحرارة وتحليل اللزوجة السائلة المتدفقة والخطأ في ضغط رأس البئر وإضافة المضخة الناقلة وتحليل مشكلة إنتاج المياه العالية ومراقبة حالة الإنتاج بشكل أساسي لاتخاذ القرار الصحيح في الوقت المناسب ، وبذلك يتم تفادي مشكلة عدم استقرار الإنتاج مع مرور الوقت.

الهدف الرئيسي من الدراسة هو تصميم نموذج شبكة لتحليل البيانات الحقلية وإيجاد الظروف المثالية والإنتاج الأمثل الذي يمكن تحقيقه في ظل الظروف التشغيلية والمعدات المتاحة وبالتالي المساعدة في اتخاذ القرار المناسب والتخطيط المستقبلي لتطوير مجال الإنتاج.

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Nomenclature

FPF: Field Processing Facilities

GNPOG: Greater Nile Petroleum Operating Company

RTO: Real Time Optimization

QC: Quality Control

OGM: Oil Gathering Manifold

WOR: Water Oil Ratio

WOR`: Derivative Water Oil Ratio

OFM: Oil Field Manager

OPCO: Operating Company

GUI: Graphical User Interface

GIS: Geographical Information System

GOR: Gas Oil Ratio

API: American Petroleum Institute

WC: Water Cut

Chapter 1

Chapter 1

Introduction

1.1 General Introduction

In production engineering, Production Optimization is a fundamental practice, its refers to the various activities of measuring, analyzing, modelling, prioritizing and implementing actions to enhance productivity of a field: reservoir/well/surface and ensure recovery of developed reserves while maximizing returns.

There are several activities to be done in production optimization such as near-wellbore profile management, Removal of near-wellbore damage, matrix stimulation or acidizing, Maximize the productivity index, Design of well completion, Optimization of artificial lift performance at field and well level, Efficiency of oil and gas transport.

This research emphasis on the following activities:

- Design of surface facilities and fluid handling capacity.
- Production system debottlenecking.

1.2 Research objectives:

The main goal of this study is to explain the impact of sustaining optimum production in case of long production stability as well as improve the well production performance, this also includes the following:

1. . To build physical model and compare simulation result with field data
2. .To identify Wells and networking problems such as:
    - Pressure distribution and bottlenecks and other related constrains to reduce back pressure on the system.
    - To analyze the issue of high-water production wells and its impact on the total production.

3. To optimize production from the networks**.**

1.3 Problem Statement:

Hamra field is facing challenges to sustain its production, which is decreasing annually. Flow lines network plays important role in delivering the production from wellhead to Field Processing Facility (FPF).Bottlenecks and back pressure in pipeline can cause rise in wellhead pressure, which can have a very strong impact on production sustainability beside high water-cut challenge which range about 71-80% for the whole field.

1.4 Hamra field background:

Hamra field is located in block 2 in South Kordufan and it was operated by Greater Nile operating company (GNPOC) which has concession in Western Upper Nile area includes the field from sedimentary basin of Muglad in interior Sudan. Later, (GNPOC) had relinquished the block to 2B(opco) operating petroleum company in 2017

Hamra field consist of 73 wells connected to six oil gathering manifolds. Most of the wells are completed in multiple formations and being produced commingled. These formations have wide variation in reservoir properties, oil type and pressure regime.

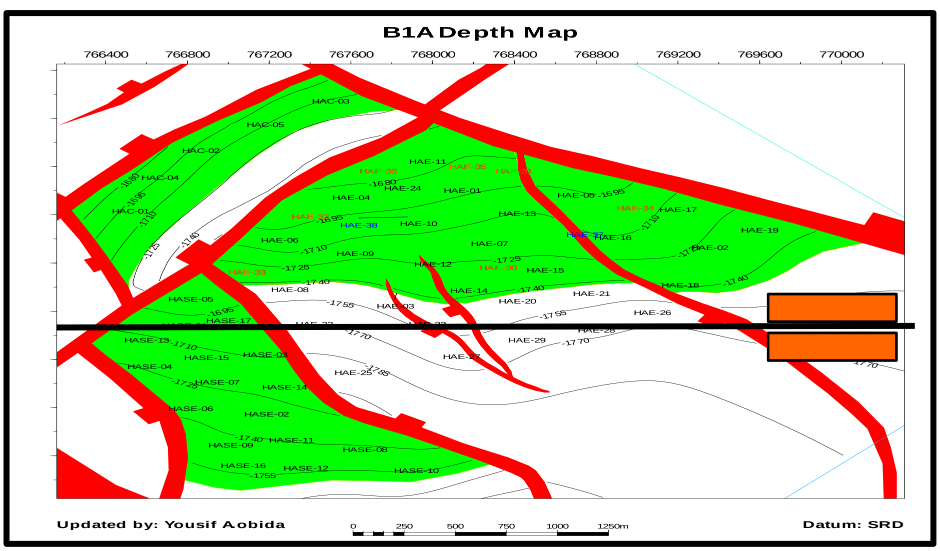


Figure (1.1): Hamra cluster & wells location

Hamra Cluster was put to production in January 2012, and it consist of five structures i.e. Hamra, Hamra Central, Hamra East, Hamra South East and Hamra south-west. With the following tables show the general information of these five structures by Oct 2016:

Table (1.1): Numbers of Wells in the five Structures

Structure	Running Wells	Gross Production (blpd)	Oil Production (bopd)	Water Production (bwpd)
Hamra	5	9344	319	9025
Hamra Central	4	2728	302	2426
Hamra East	26	15089	4772	10316
Hamra South East	15	5233	2161	3072
Hamra South West	1	750	8	742
Total	51	33144	7562	25582

Table (1.2): General properties of Hamra Cluster 2A and 2B structures

Block	Running Wells	Gross Production (blpd)	Oil Production (bopd)	Water Production (bwpd)
Hamra-2A	17	5381	1736	3645
Hamra-2B	34	27763	5826	21937
Total	51	33144	7562	25582

Chapter 2

Chapter two

Theoretical background and literature review:

2.1 Modeling approach:

An integrated business development modelling approach is often used in energy master planning studies, where the focus is on the commercial value of oil & gas and related value streams in the market while balancing the costs of production, transport, processing and storage. It provides a structured framework for analysis across the whole energy value chain in order to focus on the key business opportunities **(KJ li, Nort Thijssen and Mittendorf 2007).**

The aim of the network analysis is to help determine the optimal timing of developments of the fields, to identify bottlenecks in the network and evaluate options for removal of these bottlenecks. This analysis can also be used to help underpin investment decisions, optimize the product slate and to analyze trade-offs between, for example, energy efficiency, production and overall recovery **(KJ li, Nort Thijssen and Mittendorf 2007).**

The model helps to optimize flow and production of oil and gas, between wellhead platforms and demand locations over the defined time period given the infrastructure (e.g. production, pipelines, and compressor) constraints. The economic analysis converts output from the program into analysis of individual assets and scenarios based on costs, capabilities and prices **(KJ li, Nort Thijssen and Mittendorf 2007).**

2.2 Real time of Production Optimization:

Real Time Optimization (RTO) is a method for complete or partial automation of the process of finding good (optimal) control settings. By continuously collecting data from the plant, the data are analyzed and optimal control settings are found. These settings are then either implemented directly in the plant or they get presented to an operator. If settings get implemented directly, the RTO is said to be in a closed loop.

The main aim of RTO is to improve utilization of the capacity of a production plant to get higher throughput. The idea is to operate the plant, at every instant of time, as near optimum as possible. **(Sequeira, S.E et al 2002).**

Also Real Time Optimization RTO is defined as "a process of measure-calculate-control cycles at a frequency, which maintains the system's optimal operating conditions within the time-constant constraints of the system". **(Saputelli et al 2003).**

To achieve this, a model of the plant is optimized giving optimal control settings. The model is continuously being updated by plant measurements to better fit the actual input-output behavior of the processing facilities, wells/network, and reservoir.

A general RTO system used in for example downstream petrochemical plants consists of the following three components:

- Data validation: The input and output data are validated using data reconciliation and signal processing techniques, e.g. using material and energy balances.
- Model updating: The processing facility models, well/network models, and reservoir models are updated to best fit the input and output data available.
- Model-based optimization: An optimization problem based on the updated models is set up and solved to obtain the optimal control settings.

(Xiong, Q. and Jutan, A 2003).

2.3 Surface Network Modeling and De-bottlenecking of Production Network:

Network Model Development

A hydraulic network in PIPESIMTM is made up of single branches or segments connected at points called nodes. The segment may be just a connector or it may contain pressure loss devices such as pipes and piping equipment connected in series. Nodes can be boundary nodes (Sources and Sinks) or internal nodes (junctions). The net flow in a junction node is zero. A boundary node can be a:

- **Source node**: where fluids flow into the network; node flow rate is positive.
- **Sinks node**: where fluids flow out of the network; node flow rate is negative.

The advantage of using network modeling is that, it captures all the interactions between the components of the network, rather solving for single pipeline; such as the interaction between adjacent wells and flow lines. In the process of solving for the network equations results such as the pressure drop, holdup velocity, heat transfer and fluid temperature are calculated throughout the network.

Based discussion with various relevant departments, it was decided to follow following steps while and building network model and various sensitivity study:

- Data Collection and Validation (QC).
- Physical Model Building and Validation.

- PVT modeling.
- Multiphase Flow Correlation Matching.
- Network Balancing and fine tuning.

Data gathering is the first and foremost requirement of a model building effort. Since field is structurally and otherwise a dynamic environment it was essential that model building and validation should be done by matching model result to certain cut-off date instead of trying to match a moving target.

In order to ensure speed and efficiency on data gathering process, a detailed list of data requirement was prepared upfront. A workshop among various discipline and groups was organized to ensure clear understanding of data requirement and objective of the study. The data were manually collected from various groups and locations of GNPOC.

The surface network model will help to quickly identify and accurately quantify bottleneck and other opportunity to reduce backpressure on the system and improve production. This model will also help in further field development, pipeline tie-in / lineup, best nearby Oil Gathering Manifold (OGM) to tie-in new wells etc. The approach of building model is kept simple, robust and scalable. Scalable model will helps GNPOC to add-in well model and integrated this production model to reservoir simulator, facility model and real time data easily and quickly. The model would also assist in evaluating field operation and development plan and expedite the engineering decision process. The identified bottleneck has been ranked in order or priority (which needed immediate attention). **(Aditya Kumar 2012).**

The procedure is to build a reliable network model, to identify bottlenecks and minimize production loss. Bottlenecks in flow line can increase wellhead pressure; hence, it is crucial to find bottlenecks to detect and reduce backpressure effect on the flow line network. Implementing flow line flushing job successfully is important to maximize the production deliverability and prevent flow line blockage and backpressure **(Humoud and Mishari 2016).**

The individual objects in the network are interconnected by flow lines. These flow lines provide the main source of pressure drop in network and often the cause of bottlenecks which lead to suboptimal production. Interconnection between OGMs and flow line was added challenges in matching flow parameter.

All Well flow lines, trunk lines, OGMs and interconnections have been analyzed for flow assurance. As a result of study a number of debottleneck has been found in GNPOC pipeline network. More than 180 bottle neck points were identified in the GNPOC Flow line network. Project team with approval from management these bottlenecks were due to high pressure drops happens at below priorities:

- Priority 1 (Wellhead choke): can be easily solved by optimizing pump wherever possible by reducing speed/frequency.
- Priority 2 (OGM): requires cleaning of OGM
- Priority 3 (Trunk lines): Requires cleaning or re-routing
- Priority 4 (Flow lines): No action has been suggested as of now.

Table (2.1): Result Analyses (Number of bottleneck found in Network)

Field	Priority 1	Priority 2	Priority 3	Priority 4
Heglig	16	2	5	15
Unity	11	5	8	11
Neem	17	0	1	6
Eltoor	10	1	2	10
Toma South	9	4	2	5
Munga	7	3	0	8
Bamboo	3	1	0	3
Elnar	5	2	0	4
Diffra	6	0	0	0

The field behavior is very dynamic so challenges should be address in dynamic way. GNPOC field produces from more than 400 wells. The huge network of with complex pipeline and huge number of data will create challenges for regular updating of model. To reduce model updating workload in future there should be plan for automated model workflow and real-time data fetching system. Interconnection between OGMs and flow line with no measurements point were additional challenges while matching and fine tuning of network. **(Aditya Kumar 2012).**

2.4 Excessive Produced water:

During oil production, many problems (environmental effects, reduction of the net oil production and increases corrosion rates) were presented as a result of unwanted water production through oilfields; due to the large amount of water produced during oil production, some argue that oil industry is effectively water industry producing oil as a secondary output.

Channeling and coning are the major problems lead to excessive water production worldwide; other problems have limited prevalence.

The solution for the massive water production problems can be categorized into two groups:

- Water Control Techniques.
- Water Disposal Techniques.

it is well known that produced water has serious pollutants and causes thousands of deaths per day, mostly due to contamination of drinking water by untreated sewage in developing countries; therefore, the disposal techniques have to apply the standard regulations for environment before the water been spilt in the ground, which consequently increases the disposal costs from 30 to 40 US$ billion worldwide and affect the economic feasibility of the field.

Operators have to differentiate between different types of water entering the well bottom hole; the problems can vary from **simple** such as (tubing or casing leaks and oil water contact moving), to **adequate** problems such as (high permeability layers or conning).

When it desired to use a controlling techniques (**mechanical** or **chemical shut-off**), an adequate and timely diagnosis of the water production mechanism are required; improper diagnosis leads to ineffective treatment or inaccurate control; which consequently wasting of both time and money.

For the optimum treatment design, all data which consist of historical wells job, completion, production data, and reservoir data and the production data, must be available and revised thoroughly reviewed to ensure the wells were properly selected.

For the candidate selection criteria many different approaches are available, such as:-

- Shut-in wells or wells producing at or near their economic limit. (Minimize the risk in case of failure and reducing the treatment cost).
- Mobile oil in place, the wells at the water-out area as example is a bad candidate.
- High water-oil ratio.
- Active Natural water drive wells.

Water shut off techniques were used worldwide to avoid the massive water production such as **Chan method 1995** (log-log plot of WOR and derivative of WOR versus time) to differentiate between two coning and channeling using a three dimensional, three-phase black oil model.

Chan reported three different periods in his plots. The first period known as (departure time) and starts from the begging of production to the breakthrough time, this stage is longer for channeling than conning. (At the time of break–through), the WOR increases with time with different trends for coning and channeling. In coning, the WOR increases slowly and gradually approaches a constant value at the end of the second period. While in channeling the WOR increases relatively fast and slow down till it reaches a constant value **(Mohanned Mahjoup 2015)**.

Finally, in the third period, the value of WOR increases very fast for both mechanisms.

The work presented that Chan’s plot were found to be affective in differentiating whether the well is experiencing water coning (negative slope) or multilayer channeling (positive slope for the time derivative of water oil ratio curve).

The diagnostic plots applied in this study provide a handy method for quick evaluation of excessive water production mechanisms in order to select wells candidates for water control treatment.

Thus the aim is to discuss, diagnose, manage and evaluate the excessive water production in Hamra oil field.

In addition to illustrate the excessive water production mechanism to recommend the optimum shut off method and provide an effective treatment for the problems **(Mohanned Mahjoup 2015)**.

Chapter 3

Chapter 3:

Methodology:

3.1 Introduction on used softwares:

PIPESIM steady-state multiphase flow simulator software was built & innovated by Schlumberger, which is use to simulate individual well and surface network models. PIPESIM combines best-in-class science with an unparalleled productivity environment to enable engineers to optimize production systems from the reservoir to the sales point. These release notes describe the most significant enhancements and known limitations.

The PIPESIM steady-state multiphase flow simulator software offers complex production and injection networks analysis. The well, pipeline, and flow assurance capabilities are all within a shared common environment, powered by the most rigorous field wide solver.

The solver is suitable for networks of any size and topology, including complex loop structures crossovers .by modeling the entire production or injection system as the network interdependency of wells and surface equipment can be accounted for, and the deliverability of the system can be determined.

PIPESIM network simulation and optimization capabilities enable users to:

- Design the best well, pipeline, and facilities design.
- Identify production bottlenecks and constraints
- Optimize production from complex networks
- Quickly identify locations in the system most prone to flow assurance issues such as erosion, corrosion, and hydrate formation

- Quantify the benefits of adding new wells, compression, pipeline, etc.
- Determine optimal locations for pumps and compressors
- Design and operate water or gas injection networks
- Analyze hundreds of variables such as pressure, temperature and flow assurance parameters through Complex flow paths.
- Evaluate benefits of loops and a crossover to reduce backpressure.
- Calculate full field deliverability to ensure contractual delivery rates can be met

In this study it was decided to follow the following steps while building network model and various sensitivity study:

1. Data Collection and Validation.
2. Physical Model Building and Validation.
3. PVT modeling.
4. Multiphase Flow Correlation Matching.
5. Network Balancing and fine tuning.

On the other hand OFM simulator software has been used as indicator to identifying active wells from inactive wells.

For example:

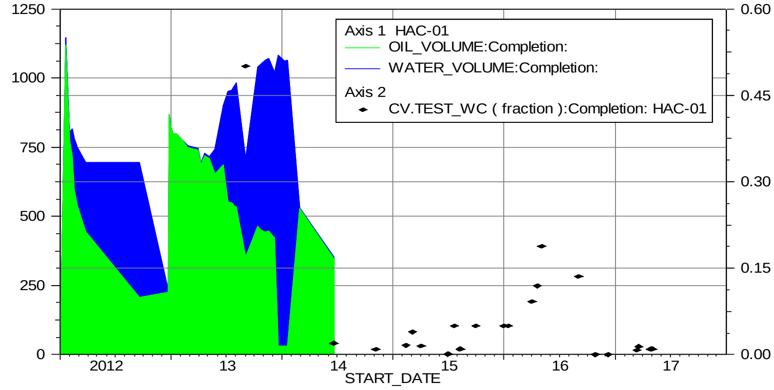


Figure (3.1): illustrate HAC-01 production status. **Moderate water production**

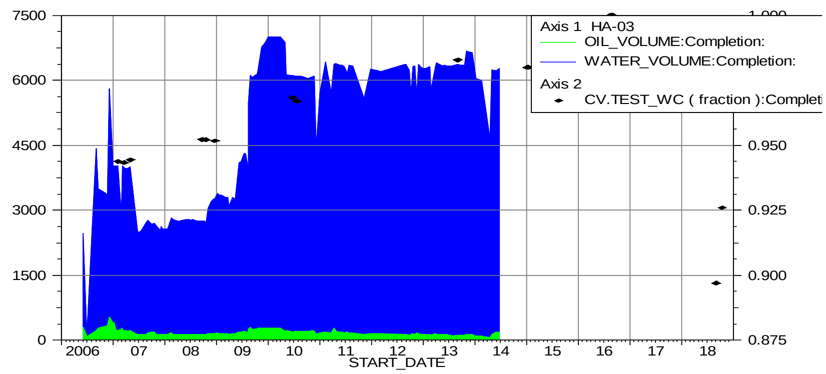


Figure (3.2): illustrate HAE-03 production status. **High water production.**

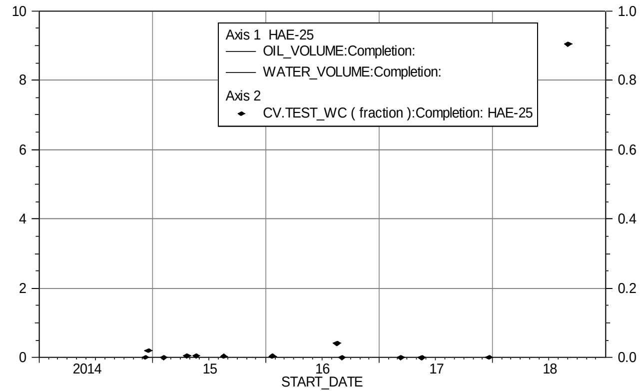


Figure (3.3): illustrate HAE-25 production status. **Inactive well.**

3.2 Data Collection:

Data Collection is the first step and foremost requirement of a model building effort. Since field is structurally and otherwise a dynamic environment it was essential that model building and validation should be done by matching model result to certain cut-off date instead of trying to match a moving target.

In order to ensure speed and efficiency on data Collection process, a detailed list of data requirement was prepared upfront. The data included horizontal distance, inner flow line diameter for wells, flow line and OGMs beside pressure survey data, production test data and well history. Meetings among various discipline and groups were organized to ensure clear understanding of data requirement and objective of the study. The data were manually collected from various groups and locations of 2B OPCO.

3.3 Physical Model Building and validation:

A hydraulic network in PIPESIM is made up of single branches or segments connected at points called nodes. The segment may be just a connector or it may contain pressure loss devices such as pipes and piping equipment connected in series. Nodes can be boundary nodes (**Sources and Sinks**) or internal nodes (**junctions**). The net flow in a junction node is zero.

A boundary node can be a:

1. **Source node:** where fluids flow into the network; node flow rate is positive.

2. **Sink node:** where fluids flow out of the network; node flow rate is negative.

3.3.1 Layer 1 FPF and 6 OGMs:

In PIPESIM graphical user interface (GUI) The network schematic has been logically organized using PIPESIM's workspace options to enable easy navigation to various parts of the model.

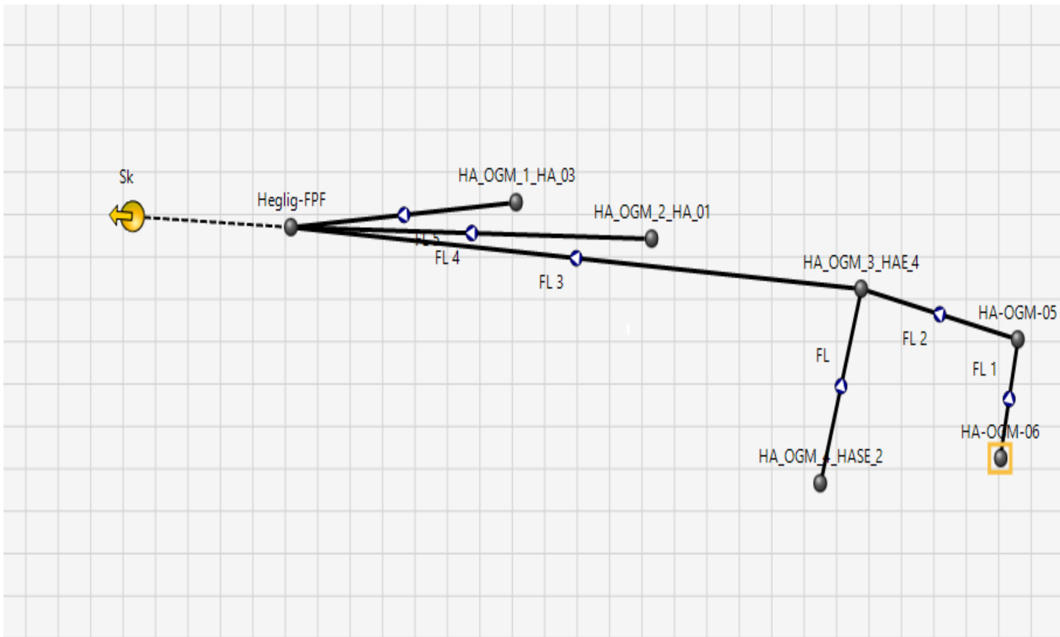


Figure (3.4): OGMs Network schematic

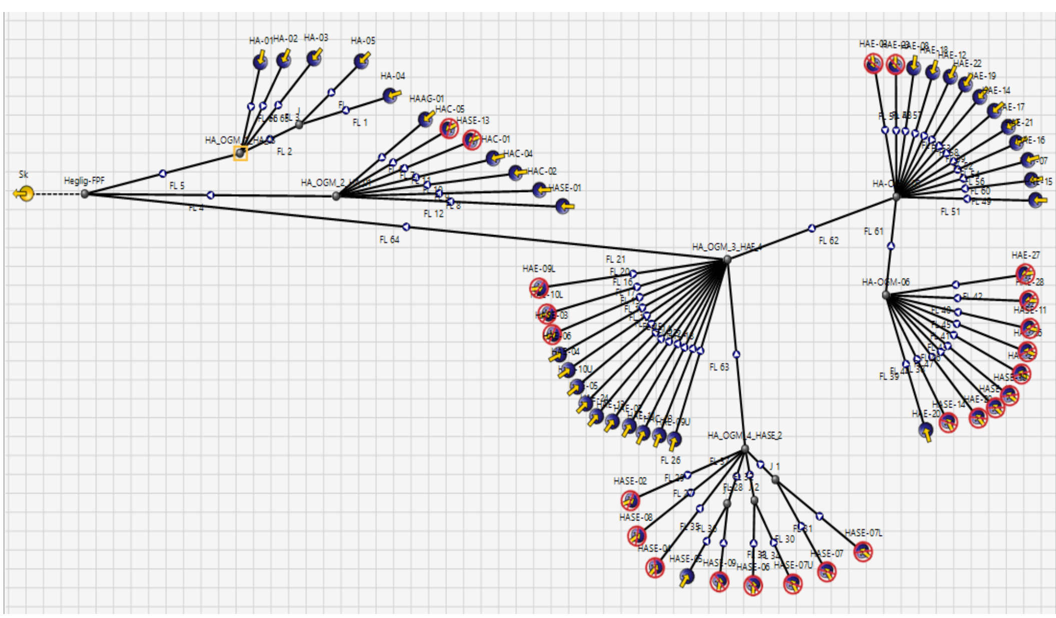


Figure (3.5): illustrate FPF, OGMs with their connected wells. Beside inactive wells

Then, wells (as source point), junctions points, connections and the field processing facility unit FPF as (sink point) all these has been located in its real locations on ground using GIS depending on latitude, longitude and elevation coordination as shown in **Table (3.1**) below:

Table (3.1): illustrate wells and OGMs Geographic coordination data

Node/Branch`	Latitude (degree)	Longitude (degree)	Elevation (ft)
HAE-04	9.92004174	29.42192596	1303.70733
HA-02	9.92048927	29.41421911	1306.56175
HA-03	9.92723399	29.4123909	1307.51312
HA-04	9.92247832	29.41146725	1304.92123
HA-05	9.92475435	29.42435051	1304.79007
HA_OGM_1_HA_03	9.92644127	29.41205481	1304.3307
HA_OGM_2_HA_01	9.918755	29.422843	1307.64438
HA_OGM_3_HAE_4	9.910946	29.440711	1307.5788
HA_OGM_4_HASE_2	9.894775	29.436202	1304.03544
HAAG-01	9.93596254	29.44102646	1307.08659
HAC-01	9.91046766	29.43050181	1305.34775
HAC-02	9.91496926	29.43367597	1304.13386
HAC-03	9.91864067	29.4394908	1304.75723
HAC-04	9.91303097	29.4317568	1308.30059
HAC-05	9.91658865	29.43591182	1303.77301
HAE-01	9.91189573	29.44531015	1307.80848
HAE-02	9.9075327	29.45631139	1304.26512
HAE-03	9.90371824	29.44233337	1307.31628
HAE-04	9.9114053	29.4403486	1303.67459
HAE-05	9.91151335	29.45037446	1308.43175

Then it’s been constructed with GIS map to be located in there real positions in ground as illustrated in **figure (3.6)** below.

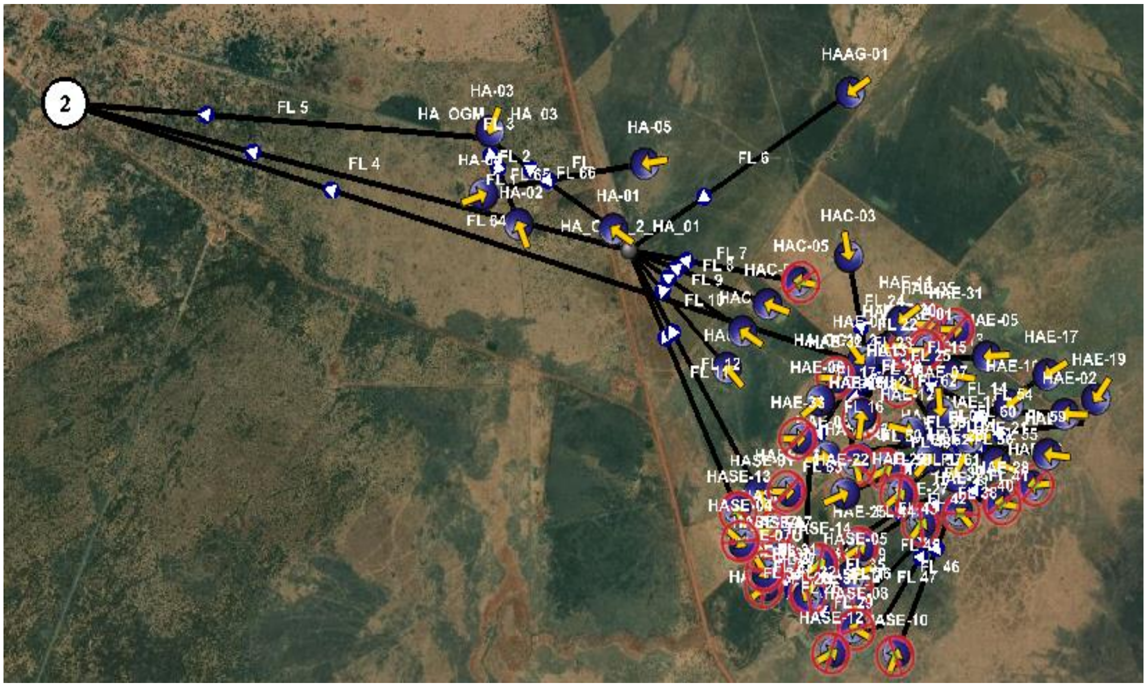


Figure (3.6): illustrate wells and OGMs in their real location.

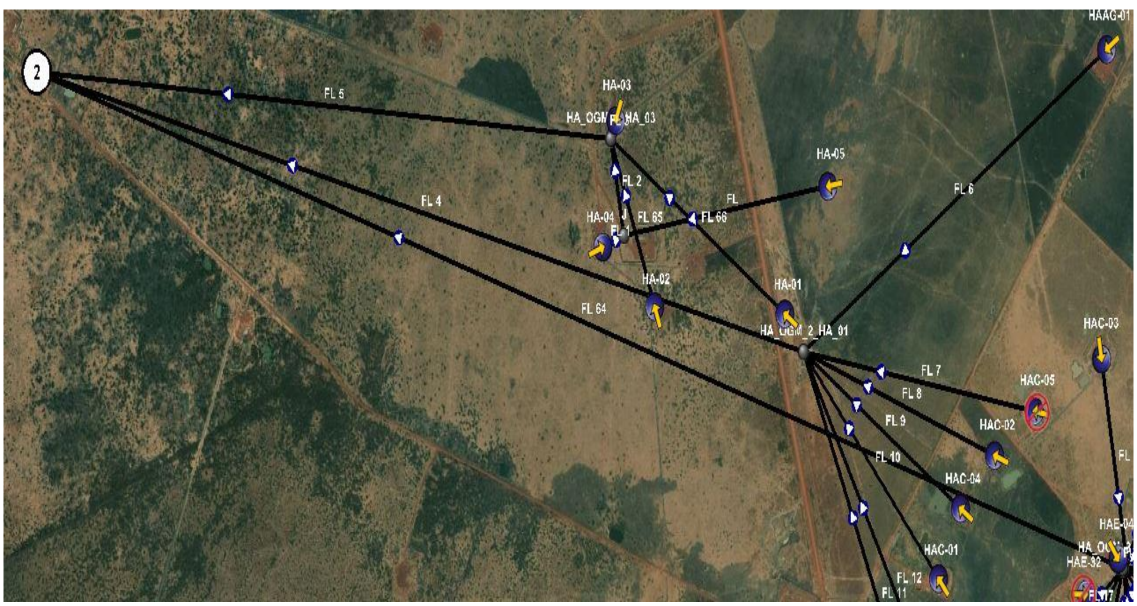


Figure (3.7): illustrate HA-OGM01and HA-OGM02.

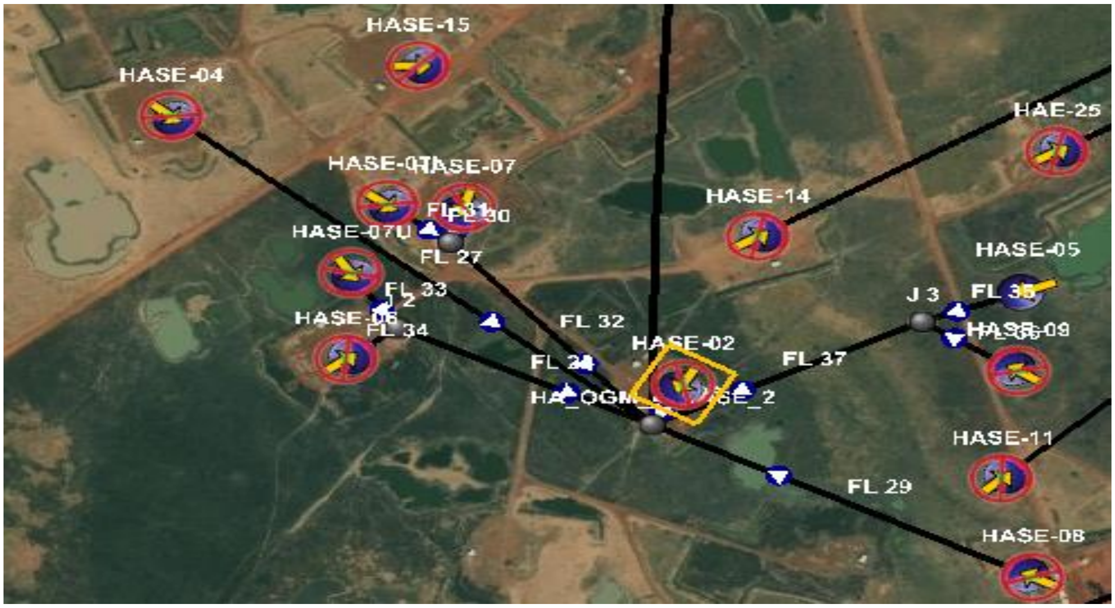


Figure (3.8): illustrate HA-OGM04 and its related wells.

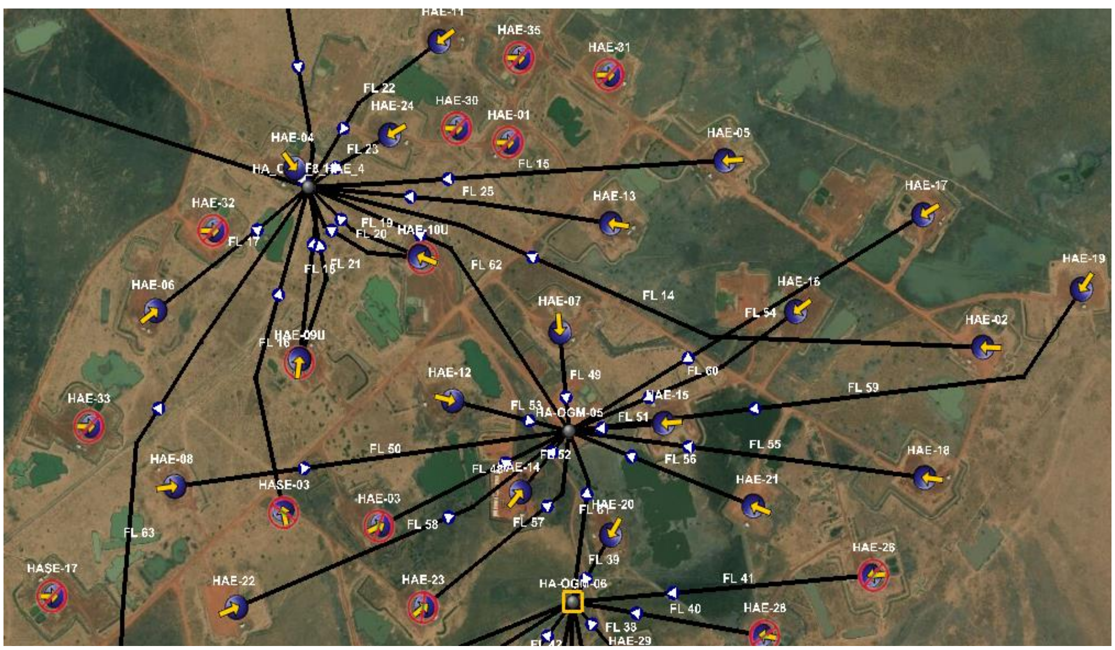


Figure (3.9): illustrate HA-OGM05 and HA-OGM06 connected to HA-OGM03.

3.3.2 Layer 2: wells and flow lines connected to OGMs:

Sources and production wells are connected to each OGM by a flow line data were input to this flow line as same as the data used to build the trunk lines as below

Six trunk lines connecting OGM's together with FPF these trunk lines data such as:

Pipe data:

1. Inner diameter
2. Wall thickness.
3. Roughness.

Profile data: which populate from GIS map such as:

1. Horizontal distance.
2. Measured distance.
3. Latitude and Longitude degrees
4. Elevation points.
5. Ambient temperature degree.

3.3.3 Layer 3: Wells Model

All well treated as source point the input data required are include:

A. PVT Data

B. Pressure/flowrate boundary conditions data:

1. Pressure or flowrate (either one of them)
2. Temperature.

Table (3.2) entering well model data and boundary condition properties

Well	Temp (° C)	WC%	Flow rate	API
HA-01	42	94	405	28.96
HA-02	70	97.94	2,256	30.09
HA-03	67	97.5	3,370	26.83
HA-04	74	96.4	2,600	28.96
HA-05	70	96.8	1,920	28.7
HAAG-01	36	14	158	21.31
HAE-01	67	95.4	2,880	35.56
HAE-02	32	0.3	85	33.14
HAE-04	50	96.6	2,400	35.44
HAE-05	45	96.4	1,760	34.36
HAE-06	60	96.2	2,000	33.43
HAE-07	49	97.85	3,000	34.19
HAE-08	32	7	155	35.3
HAE-10U	44	93	1,980	35.25
HAE-11	33	36	1,520	35.14
HAE-13	72	93.5	3,256	35.85

3.3.4 PVT Data and fluids properties:

The data required include: Water cut, GOR and API As illustrated in **Table (3.2)** above:

3.4 Flow correlation:

For fluid viscosity data, flow correlation was selected from variety of correlation provided by software based on best match for under saturated oil (Vasquez & Beggs) correlation was selected and for dead oil (Beggs &Robinson) correlation was selected.

3.5 Network Balancing and fine tuning:

After applying previous steps to validating the data and construct the model. The data has been balanced then the model checked and Verified for any errors, therefore the model became ready and it was run successfully.

Chapter 4

Chapter 4

Result and discussion

In this chapter we will discuss the results after running and validating the data.

The production optimization study for Hamra Field was successfully conducted, the Analysis Results and main findings are **include**:

- Surface Network.
- Flow direction result.
- Pressure Distribution and identification of back pressure and other related constrains.
- Describe the effect of the high crude viscosity with temperature variations.
- Describe the flowing liquid viscosity distribution.
- Compare the pressure distribution estimation with the current field data.
- Analyze the effect of the transfer pump on the bottle neck release and oil rate incremental.
- Excessive water production analysis.

4.1 Network:

The figure (4.1) illustrate the built model (Network) includes active and inactive wells, flow lines, OGMs, trunk lines, connection point as well as sink.

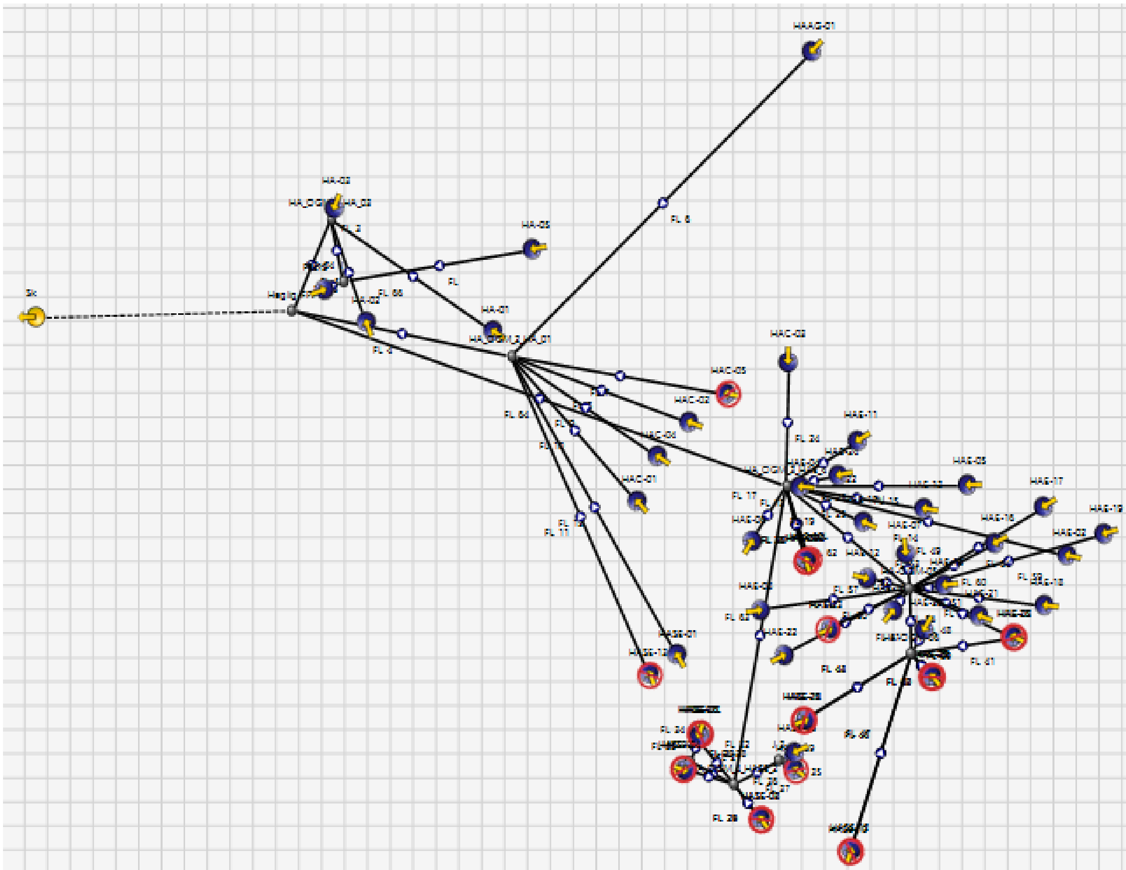


Figure (4.1) Network model.

4.2 Flow direction:

After running the model the node/branch results shows network running forward smoothly

Table (4.1): illustrate checking flow direction result

Node/branch name	Flow direction	liquid rate	Oil rate	Water rate	W/C%
HA-01	forward	405	24.3	380.7	94
HA-02	forward	2256	46.4736	2209.526	97.94
HA-03	forward	3370	74.14	3295.86	97.8
HA-04	forward	2600	70.2	2529.8	97.3
HA-05	forward	1920	57.6	1862.4	97
HAAG-01	forward	114	2.28342	111.7166	97.997
HAC-01	forward	166	155.708	10.292	6.2
HAC-02	forward	86	81.872	4.128	4.8
HAC-03	forward	89	3.6045	85.3955	95.95
HAC-04	forward	2201	48.422	2152.578	97.8
HAE-02	forward	63	62.811	0.189	0.3
HAE-04	forward	2192	74.528	2117.472	96.6
HA-OGM-05_HA_OGM_3_HAE_4	forward	3752	947.697	2804.303	74.74155
HA-OGM-06_HA-OGM-05	forward	84	58.8	25.2	30
HASE-01	forward	527	47.957	479.043	90.9
HASE-05	forward	1186	47.44	1138.56	96
J 3_HA_OGM_4_HASE_2	forward	1186	47.44	1138.56	96
J_HA_OGM_1_HA_03	forward	4520	127.8	4392.2	97.17257
Sk	forward	31148	2787.63	28360.37	91.05037

4.3 Pressure distribution results:

The pressure distribution results shows there is no abnormal values in all nodes and the pressure ranges from 170 psi up to 212 psi.

The figure (4-3) below illustrate total distance VS pressure for all HA-OGMs, Due to the effect of the high viscosity of the mixture and the difference in temperatures a back pressure is occurred, this will act like a bottleneck increasing the landing pressure at HA-OGM-02 and HA_OGM -04. On the other hand there is no abnormal pressure values in the rest of HA-OGMs.

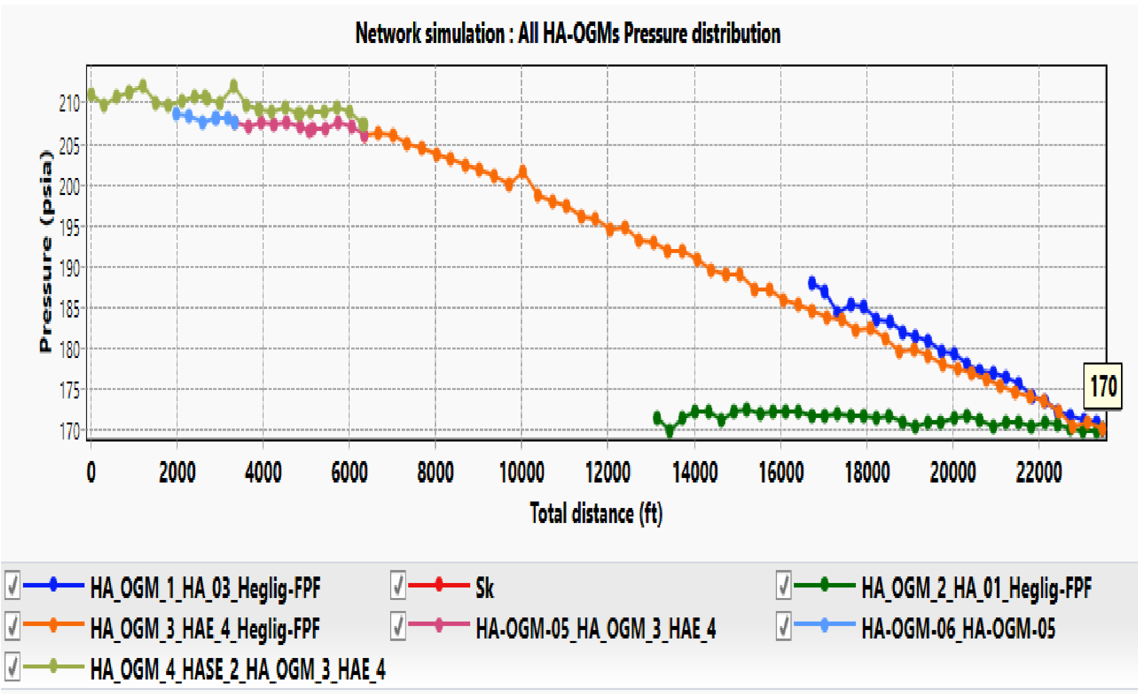
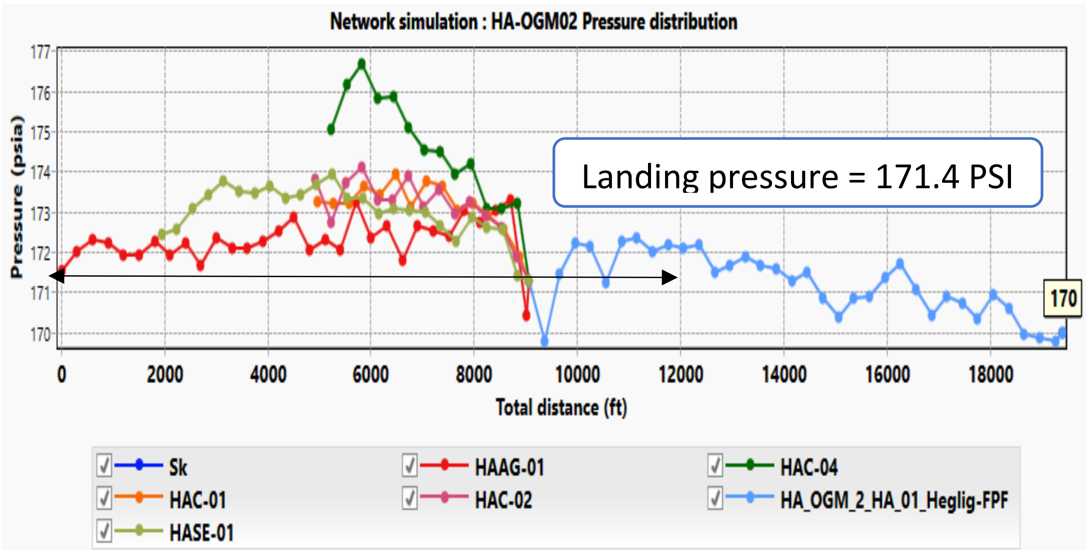
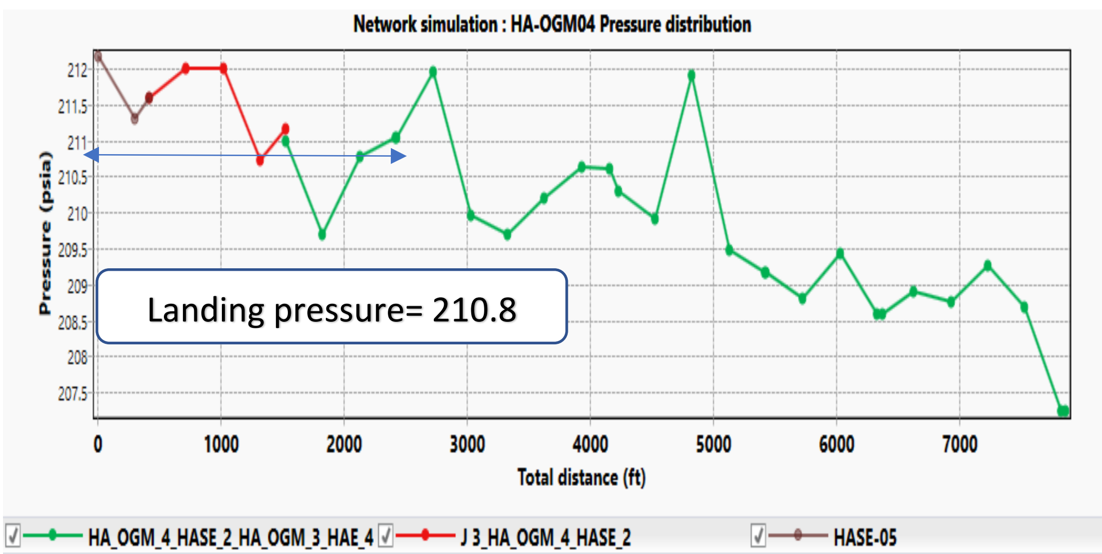


Figure (4.3): All OGM Pressure Distribution Result



The figure (4.4): Illustrate the back pressure in HA-OGM02



The figure (4.5): Illustrate the back pressure in HA-OGM04

4.4 Temperature distribution:

The figure (4.6) below illustrate total distance VS Temperature for all HA-OGMs network.

Generally, the temperature drops with distance which causes increase in viscosity, here in this figure there is no abnormal values as shown below except HA-OGM06. And to solve the problem surface heater can be added to the wells flow line in order to heat the oil and sustain temperature value so as to reduce the viscosity.

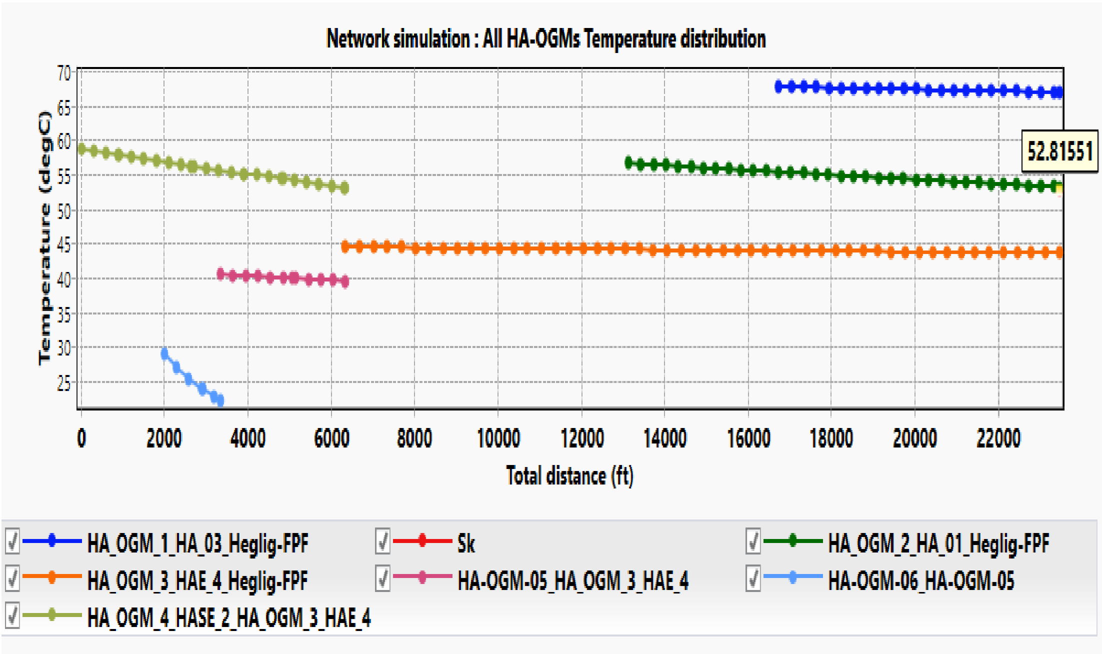


Figure (4.6): All OGM Temperature Distribution

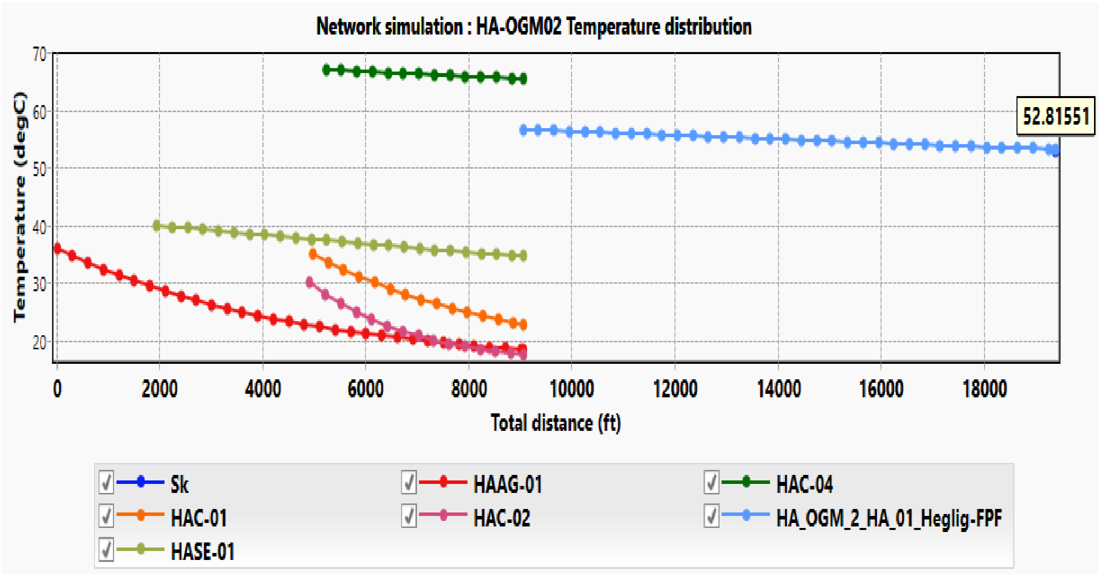


Figure (4.7): Illustrate HA-OGM02 have no abnormal value for temperature distribution.

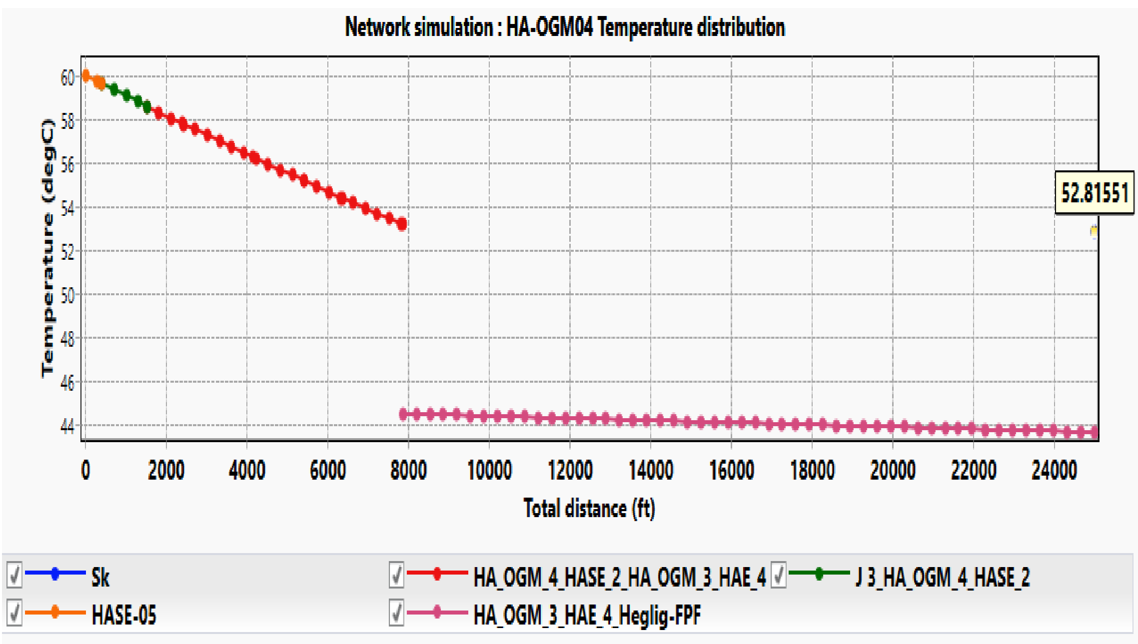


Figure (4.8): Illustrate HA-OGM04 have no abnormal value for temperature distribution.

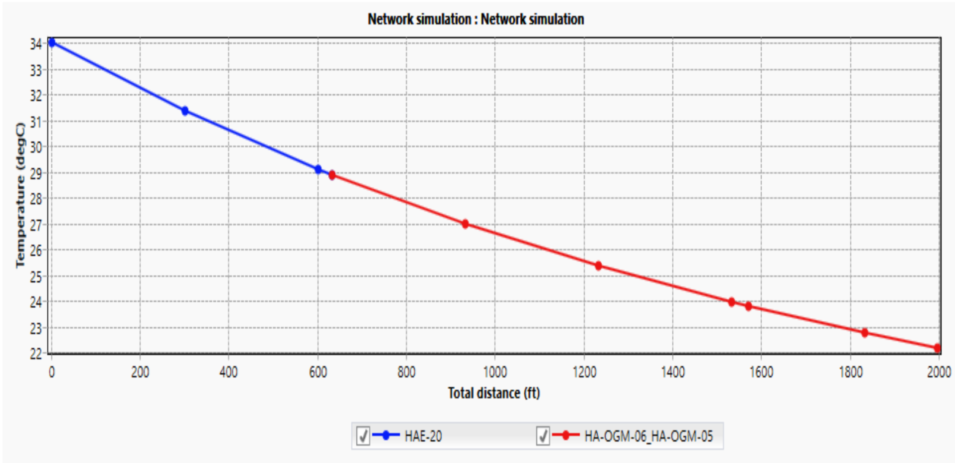
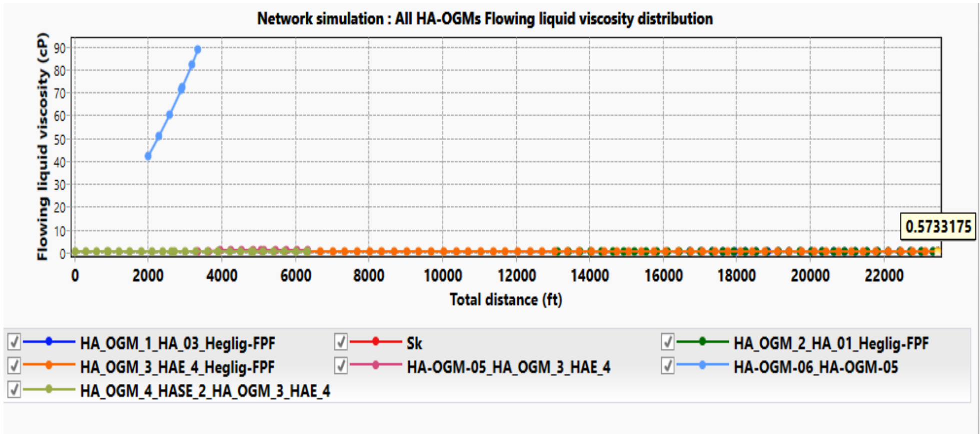


Figure (4.9): Illustrate abnormal temperature decline for HA-OGM06 which decline from 34˚C to 22˚C

4.5 Flowing Liquid Viscosity Distribution:

Generally, the viscosity increase with distance due to decrease in temperature which may cause back pressure on producing wells, here in this figure there is no abnormal values as shown below except HA-OGM06 and due to its high pressure value (207 Psi) hasn't clearly effect on oil flowing.

And to solve the phenomena adding surface heater to it can be recommended in order to heat the oil and sustain temperature value or adding chemical in order to reduce the viscosity. Also transfer pump can be attached to OGMs in order to increase transfer rate and decrease the back pressure for de-bottleneck purpose.



The figures (4.10): Illustrate total length VS Flowing liquid viscosity.

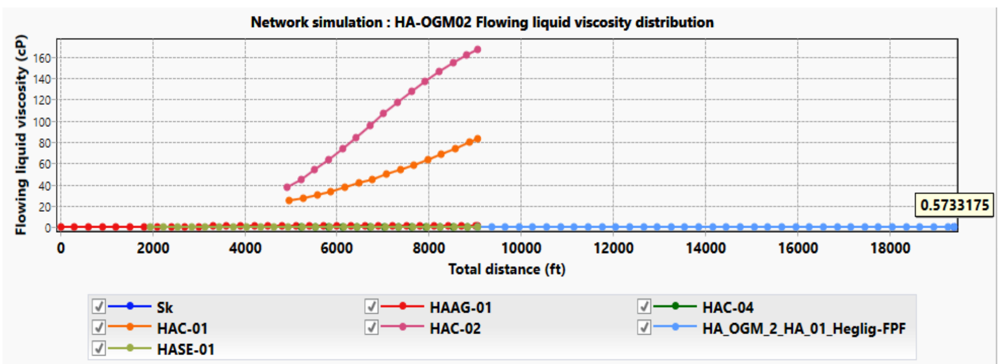


Figure (4.11): Illustrate gradually increase in viscosity value for HAC-01 and HAC-02 wells

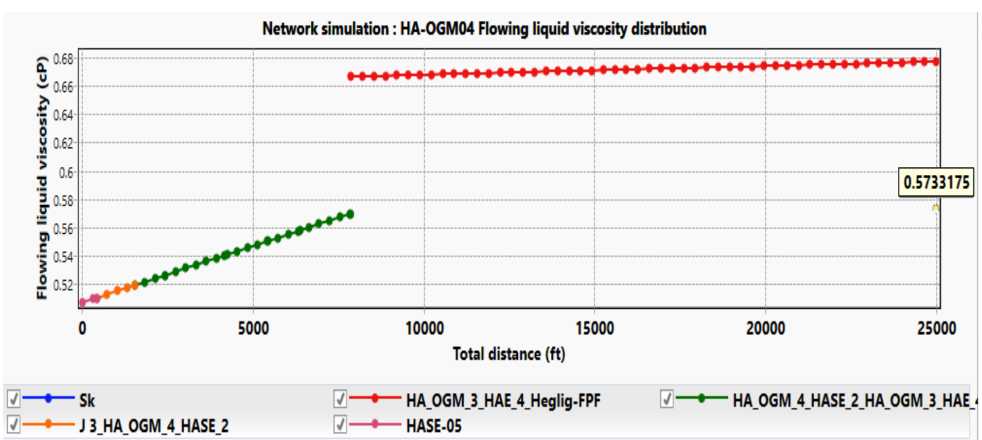


Figure (4.12): Illustrate normal viscosity values for HA-OGM04.

4.6 Pressure Difference results:

Table 4.2 illustrate comparison between the actual data and the model data in term of pressure:

	Well-HEAD Pressure	PIPESIM Pressure Estimation	Error %
HA-01	2137.37157	1296.351	64.87599
HA-02	827.36964	1289.892	-35.8574
HA-03	1654.73928	1285.467	28.7267
HA-04	1585.79181	1298.072	22.16517
HA-05	1378.9494	1321.522	4.34555
HAAG-01	2068.4241	1182.61	74.90332
HAC-01	1654.73928	1194.534	38.52593
HAC-02	1792.63422	1198.243	49.60523
HAC-03	1241.05446	1428.109	-13.0980
HAC-04	1206.580725	1206.936	-0.02944
HAC-05	**Down hole problem**		

HAE-01	NA		
HAE-02	1516.84434	1430.936	6.003646
HAE-03	**Down hole problem**		
HAE-04	1241.05446	1432.918	-13.3897
HAE-05	2068.4241	1418.461	45.8217
HAE-06	1585	1407.728	12.59277
HAE-07	1310.00193	1425.977	-8.13305
HAE-08	1516.84434	1435.118	5.69474
HAE-09L	**Down hole problem**		
HAE-09U	1378.9494	1420.989	-2.95847
HAE-10L	**Down hole problem**		
HAE-10U	1378.9494	1421.21	-2.97356

	Well-HEAD Pressure	PIPESIM Pressure Estimation	Error %
HAE-11	1999.47663	1431.169	39.709330
HAE-12	1310.00193	1427.256	-8.215349
HAE-13	1378.95	1430.497	-3.603432
HAE-14	1447.89687	1434.742	0.9168805
HAE-15	1378.9494	1432.59	-3.744309
HAE-16	1378.9494	1427.531	-3.403190
HAE-17	1723.68675	1423.854	21.057829
HAE-18	1378.9494	1429.05	-3.505867
HAE-19	1378.9494	1424.272	-3.182159
HAE-20	1378.9494	1430.61	-3.611088
HAE-21	1275.528195	1243.015	2.615672
HAE-22	1310.00193	1245.606	5.1698474
HAE-23	**Converted to water injector**		
HASE-01	2413.16145	1188.937	102.9679
HASE-02	NA NA		
HASE-03			
HASE-04			
HASE-05	1723.68675	1462.866	17.829436
HASE-06	NA NA **Down hole problem** NA **Down hole problem** NA NA		
HASE-07			
HASE-07L			
HASE-07U			
HASE-08			
HASE-09			
HASW-01			

The Error in the pressure estimation is mainly due to the differences in the solution for this issue could be adapting the same surface heating techniques an in HAC-01 and HAC-02 in the non-thermal wells till its W.C increasing and therefore decrease the effect of the high viscous crude.

Operational condition where the simulator is failed to predict the exact field scenario. But this error could give an indication on which wells have more problems in the surface, from this analysis we can find that all the low W.C wells have a massive error.

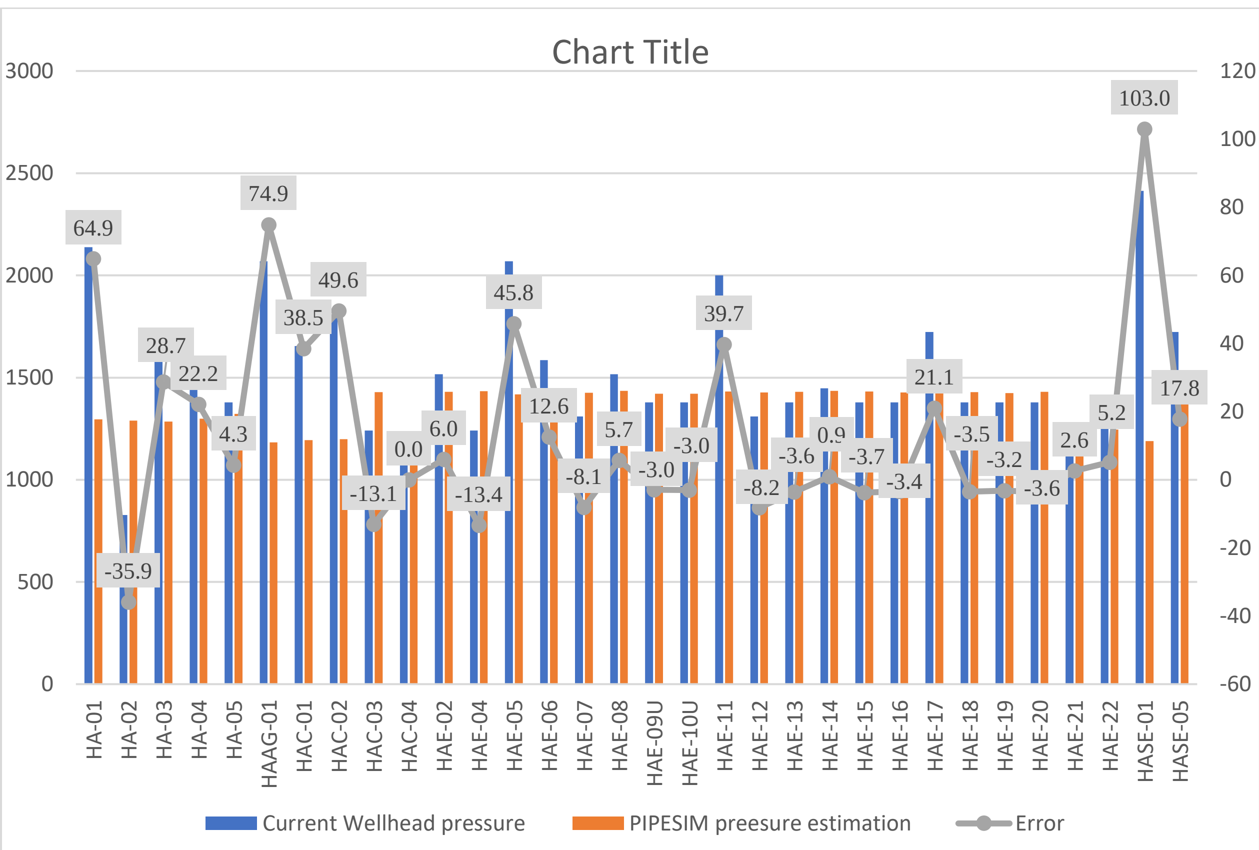


Figure (4.13) current V.S estimated pressure difference and Error result

4.7 Analyze the effect of the transfer pump on the bottle neck release and oil rate incremental:

After installing 2 Transfer generic pumps and set their operational conditions such as Horsepower to (10Hp) for HA-OGM02 and HA-OGM04 to relief their exerted back pressure.

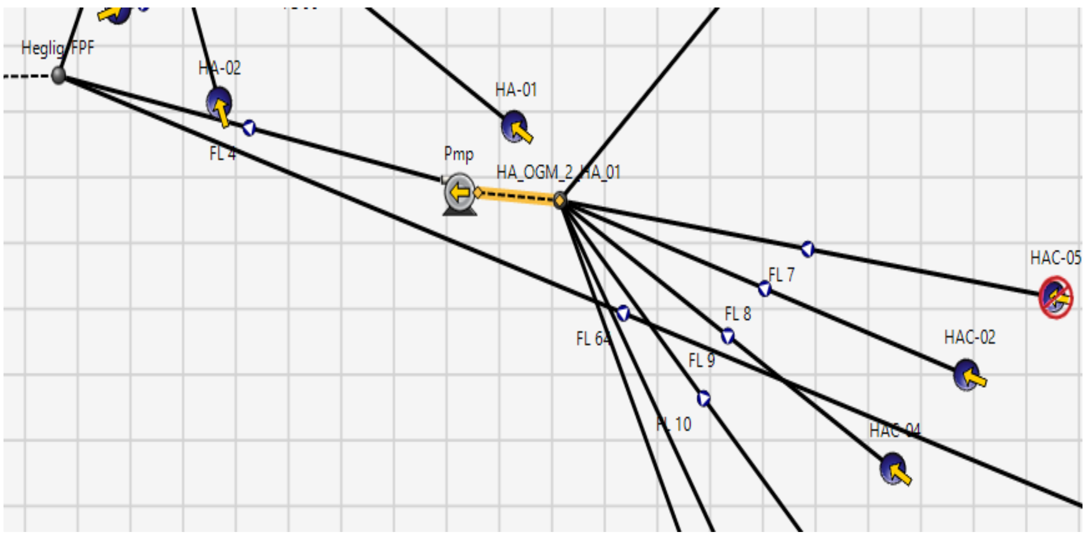


Figure (4.14): illustrate installing transfer Pump (Pmp) for HA-OGM02

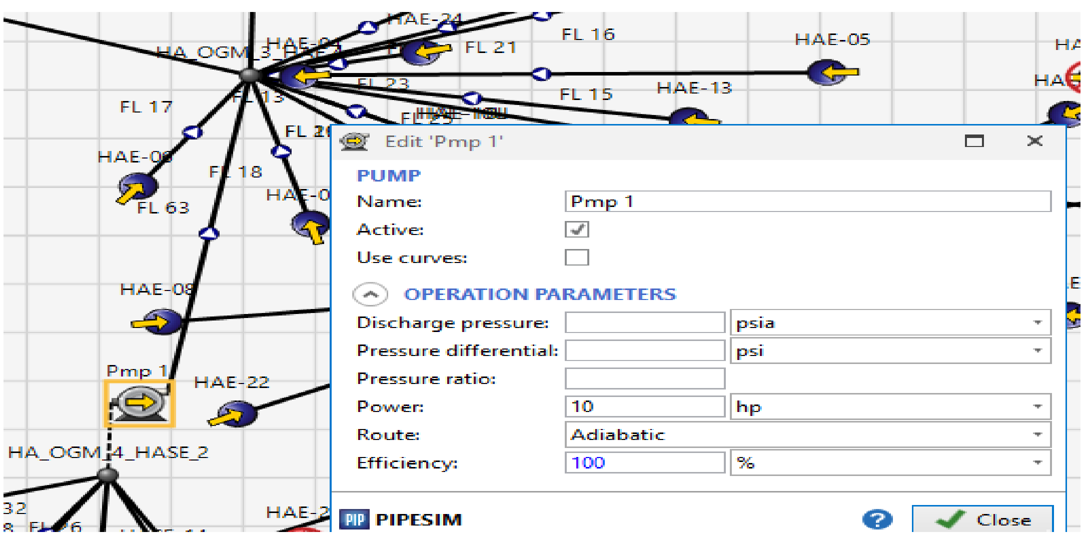


Figure (4.15): illustrate installing transfer Pump (Pmp1) for HA-OGM04

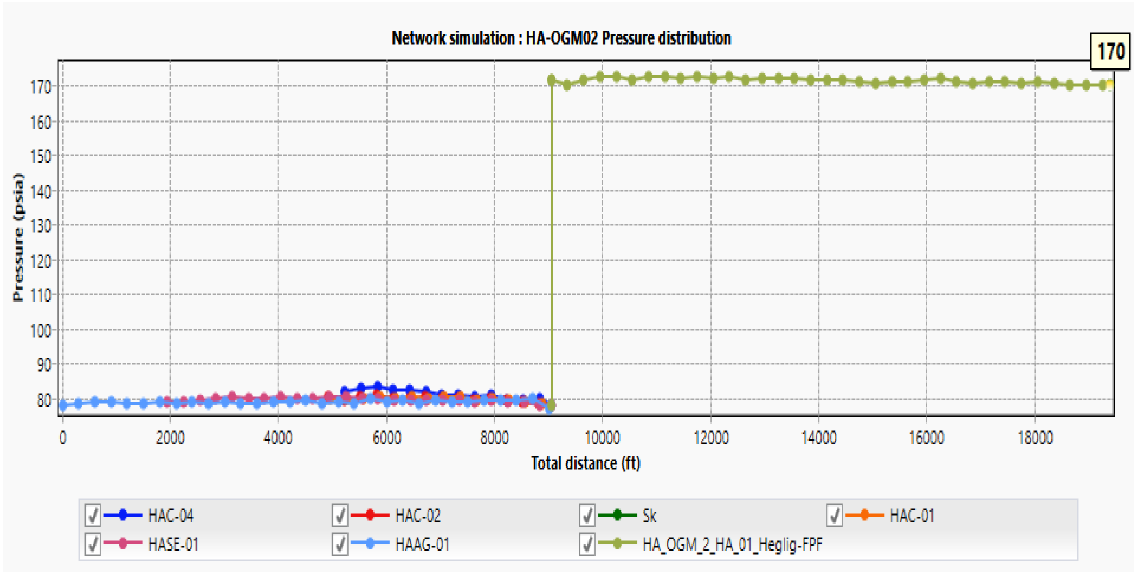


Figure (4.16) illustrate Back pressure release after installing Transfer generic pump for HA-OGM02

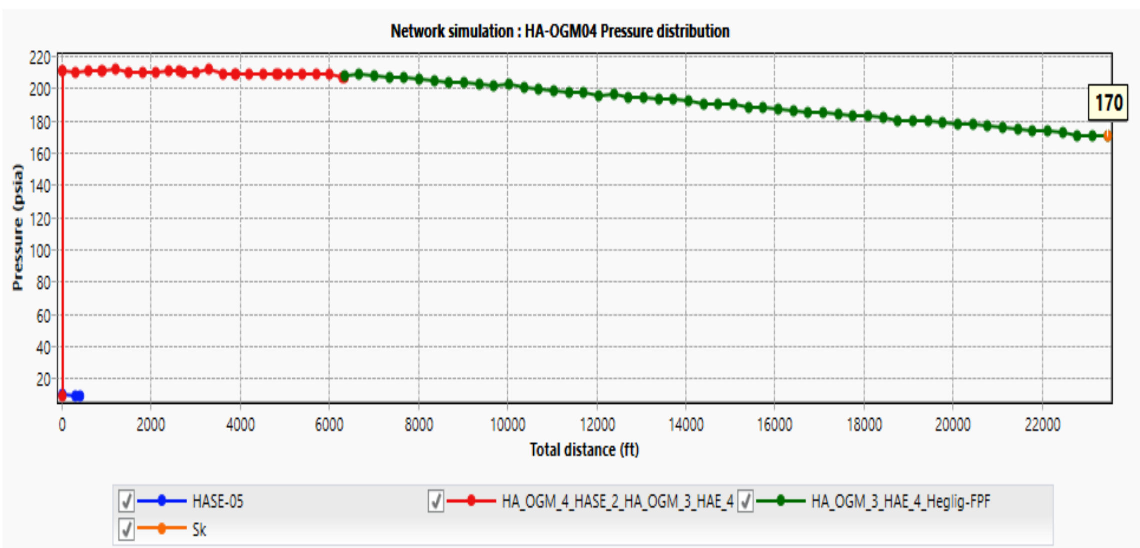


Figure (4.17): illustrate Back pressure release after installing Transfer generic pump for HA-OGM04

With every pump frequency decrease the oil became more mobile and have chance to flow through water thus, it achieve an incremental in oil ratio.

4.8 Hamra Excessive water analysis:

The WOR/WOR` analysis revealed that all the wells suffer from channeling due to high permeability streaks, which is a very complicated problem due to the effect of the mobility difference between the oil and the water. As illustrated I the next figures (4.18), (4.19), (4.20) below for high, moderate, and low water cut as examples.

With every frequency increase the water became more mobile and flow faster than the oil.

Thus, decreasing the frequency would help to increase the recovery.

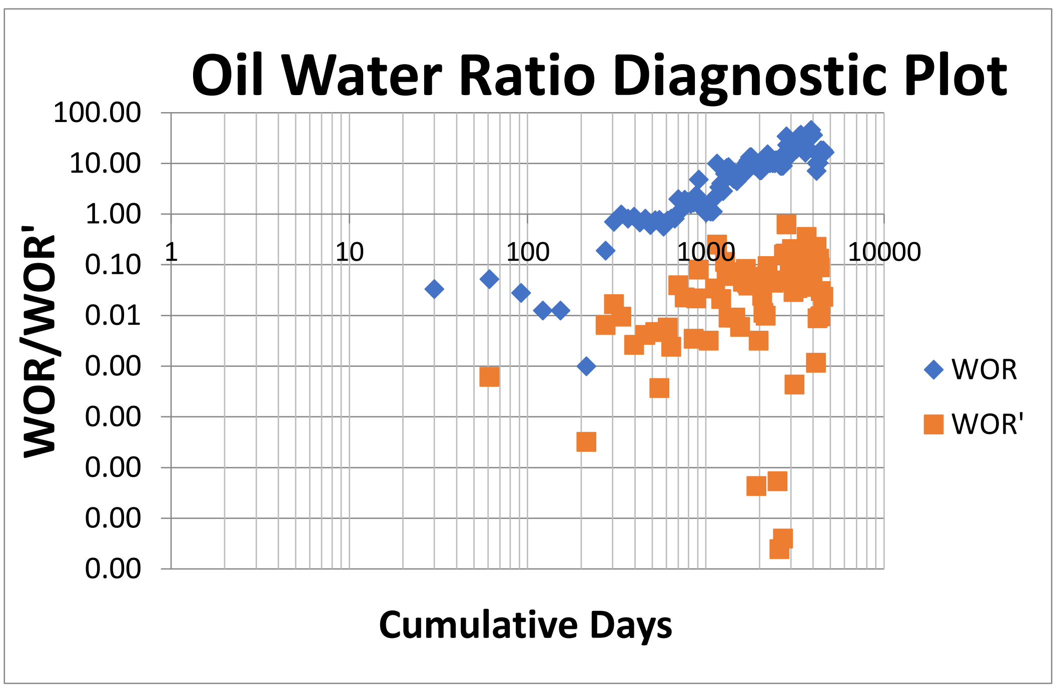


Figure (4.18): Illustrate Water Oil Ratio analysis for HA02 with 97.79% W/C.

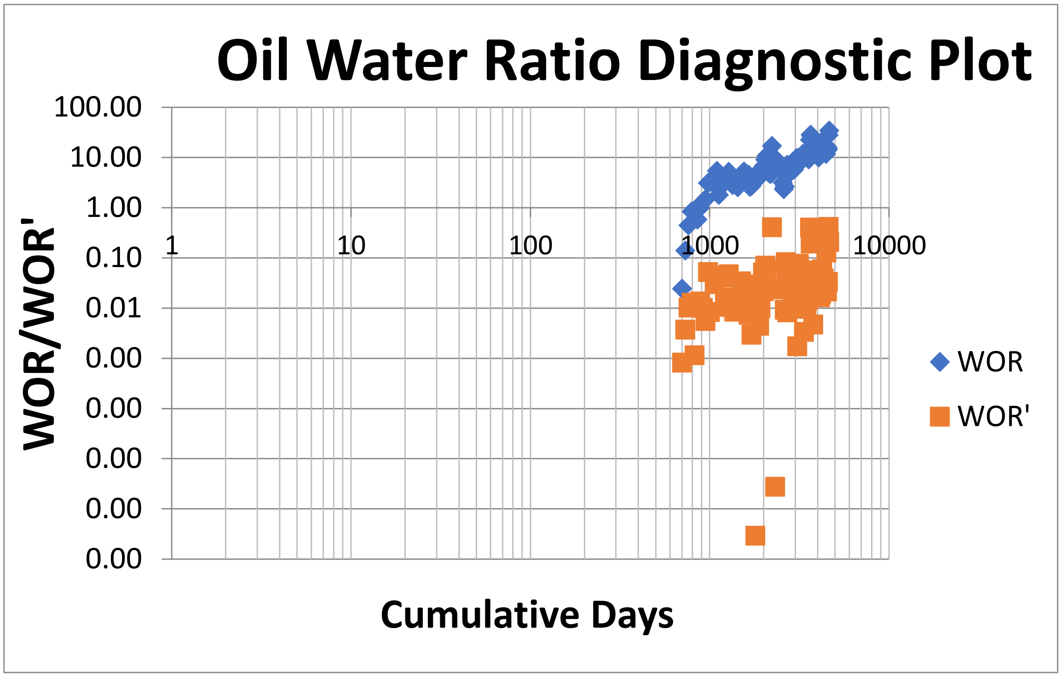


Figure (4.19): Illustrate Water Oil Ratio analysis for HAE-11 with 40% W/C

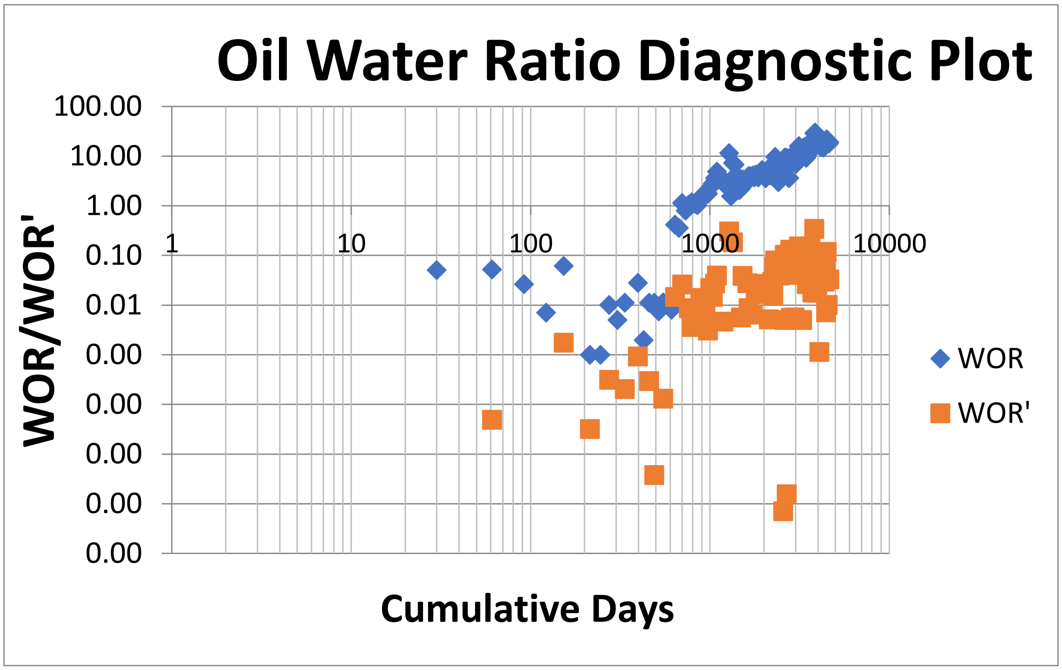


Figure (4.20): Illustrate Water Oil Ratio analysis for HAE-17 with 9% W/C

4.9 Well problems scenarios:

Scenario 1:

The result had shown that in HA-OGM02 wells, HA-AG01 became out of economical production scheme which cross 9042 ft. and has 2.2 STB/d oil beside 111.7 STB/d water with 98% w/c.

Also HAC-04 with 48 STB/d oil beside 2152 STB/d water with 97.8% w/c.

So, it recommended to be shut in as the HA-OGM02 anyway will be support by transfer generic pump to overcome the back pressure happened.

Table (4.3) Illustrate decreasing water cut ratio

			STB/D			
	Case	**pressure (PSI)**	**liquid rate**	**oil rate**	**water rate**	**W/c %**
HA-OGM02	**Before**	**171**	**3094**	**336.2**	**2757.8**	**90**
	After	**168.7**	**779**	**285.6**	**493**	**63**
FPF	**Before**	**170**	**31150**	**2787**	**28360**	**91**
	After	**170**	**28833**	**2736**	**26096**	**90**

Scenario 2:

The results had shown phenomenal values for flowing viscosity at inlet of their OGM1`s for wells:

Table (4.4): phenomenal values for flowing viscosity

	Wells	viscosity (Cp)
HA-OGM02	HAC-01	80
	HAC-02	170
HA-OGM03	HAE-02	220
	HAE-08	175
HA-OGM06	HAE-17	81
	HAE-18	172
	HAE-22	94

It's recommended to add heater through flow line route for more flowing facilitation.

Chapter 5

Conclusion and Recommendations

5.1 Conclusion

- Hamra field models which comprise surface flowlines network and wells have been successfully constructed.
- The PIPESIM Multiphase flow simulator and its GIS integration was used to create the field network with 51 producer and 6 HA-OGMS.
- This analysis was done to optimize the production in Hamra field surface network and identifying its obstacles.
- Hamra Field surface flowlines network deliverability was investigated in the current operating condition.
- The models are ready for field optimization under different operating conditions and should be updated regularly.
- The total flow rate was calculated and compared with the current daily report estimation
- A net production gain by the above production optimization can assist to sustain Hamra target production rate for coming years.
- The main reason errors in pressure between the PIPESIM estimation and the current estimation is the variation in flow lines viscosity and W.C difference.
- Finally, this thesis confirms that modeling network analysis can help to bring production closer to the technical potential of the Field production. And it will to better understand the entire field performance and give some enlighten about the production situation in Hamra Field.

5.2 Recommendations:

1. As this thesis focus on identifying actual bottlenecks and future bottlenecks, accurate representation of the network is crucial.

2. It’s recommended to monitoring water production ratio for different segments to not effect on each other.

3. In addition adding heaters through Flow lines/trunk lines routes to facilitate the oil flowing rate.

4. More precise data is key to success and that design data of equipment and pipelines alone is not sufficient and to gain reasonable result.

5. It’s crucial that the client is a member of the study team.

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