Journal Homepage: http://ijcpe.uobaghdad.edu.iq
Iraqi Journal of Chemical and Petroleum Engineering
Vol. 25 No. 2 (June 2024) 161 – 174
EISSN: 2618-0707, PISSN: 1997-4884

Gas Lift Optimization for Zubair Oil Field Using Genetic Algorithm-Based Numerical Simulation: Feasibility Study

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Abstract

The gas-lift method is crucial for maintaining oil production, particularly from an established field when the natural energy of the reservoirs is depleted. To maximize oil production, a major field's gas injection rate must be distributed as efficiently as possible across its gas-lift network system. Common gas-lift optimization techniques may lose their effectiveness and become unable to replicate the gas-lift optimum in a large network system due to problems with multi-objective, multi-constrained & restricted gas injection rate distribution. The main objective of the research is to determine the possibility of using the genetic algorithm (GA) technique to achieve the optimum distribution for the continuous gas-lift injection flows in the structure of the network of Zubair, oil field with 10 gas-lift injected wells. This will be done through numerical simulation and modeling studies. The overall enhancement of the filed production rate is found to have increased from 15767 STB/day to 19847 STB/day. The well's reservoir pressure and water cut sensitivity studies are carried out to study the possible impacts of these elements upon the well and its efficiency through the course of the field. Our understanding of the potential benefits of utilizing gas lift techniques in a field from a technical and economical point of view is deepened by the use of examples from economic analysis. Furthermore, even though the idea of employing GA in this manner is not new, this work discusses GA-based optimization methodologies for increasing the oil production rate by using gas lifting in a Zubair oilfield. In order to assign gas injection rates to specific wells in a network throughout the field using limited gas injection rates, the model for optimization will be laid out step-by-step making it simple to understand and employ as a guide, especially for the front-line production technicians involved in the development and design of gas-lift systems.

Keywords: Gas Lift Optimization; Gas Lift; Numerical Simulation; Genetic Algorithms; Zubair Oil Field.

Received on 06/10/2023, Received in Revised Form on 03/02/2024, Accepted on 04/02/2024, Published on 30/06/2024

https://doi.org/10.31699/IJCPE.2024.2.15

1- Introduction

The oil wells start to produce as a result of the reservoir's natural depletion mechanism. Artificial lift methods are implemented when the natural energy decreases [1]. When the reservoir pressure is insufficient to supply a well with a sustainable oil production rate, the artificial lift technique is frequently utilized to improve oil production rates. As energy demand has increased and mature fields' pressures have decreased, artificial lift techniques have become more and more important [2-4].
The gas lift technique is the only type of artificial lift that involves injecting gas primarily through valves into the tubing through an annulus in order to reduce the fluid's density and, as a result, reduce the necessary bottom pressure, which increases the rate at which oil is produced [5-7].

The gas-lift method is crucial for maintaining oil output when natural reservoir energy runs out, especially from older fields. Many huge fields use gas lift techniques to increase economic output [8].

Gas injection rate, injection pressure, availability for lift gas, compressors capabilities and water handling facilities are among the limitations that come with gas lift operation. These restrictions must be considered during the optimization process. It is a difficult task to take these constraints into account in order to determine the best lift gas injection rate allocation for each well in a network [9]. Increasing the rate of gas injection in a well results in an increase in oil output; however, if the rate is increased too much, production declines because of the extra intrusive frictional constraints: this phenomenon causes the oil rate versus gas injection rate curve, also referred (GLPC), to take on a dome-like shape [10].

Gas allocation problems typically involve fixed parameters due to earlier selection and installation decisions. Consequently, the rate of injected gas becomes the only variable element in these calculations [11]. A facility's changed parameters, such as injecting depth, tube diameter, and compressor, may be optimized when methods for optimization are used in the design phase [12].

Al-Fatlawi et al. (2015) set out to explore the potential of using gas lift as a solution for increasing oil production

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in Iraq's giant oil field. To achieve this, they devised a developed model that considered complexity due to shortage data of each of PVT, vertical pressure drops, wellhead temperature, and productivity index. Then, they ran two scenarios using this model: one that aimed to maximize oil production with a set bottom hole pressure constraint and another that maintained the same constraint while keeping the gas-oil ratio in check [2].

Odah et al. (2023) focused on maximizing oil production in an Iraqi oil field using gas lift optimization. The study identified six key variables that impact oil production: wellhead pressure, reservoir pressure, water cut, tubing diameters, casing pressure, and depth of injection. The primary variable of interest was the amount of injected gas. Using PROSPER software, the study analyzed a network of 16 wells in the Buzrgan oil field and sought to identify the optimal gas injection rate for each well. The objective was to determine the highest possible oil production rate for the field through gas lift optimization [13].

The subject of gas lift optimization has been studied using a variety of optimization techniques. According to Peixoto et al. (2015), these algorithms can broadly be categorized into two groups: numerical approaches and meta-heuristic methods. The conventional numerical methods, such the equal slope method, are usually thought of as being based on repeated plots or computations with absolute results. The difficulty with these methods is that they become more complex as the number of parameters increases [14].

The AI heuristic methods are alternative methods for gas lift optimization that are based on random selection such that their various iterations arrive at different conclusions. Their advantage is that they can solve complicated issues much more quickly and effectively than numerical methods, particularly in current problems where there are many input parameters [15].

To allocate the lift injection of gas rate across all wells as effectively as feasible, different gas-lift optimization methods have been developed within certain facility restrictions [16]. The multivariate optimization strategies for the optimization of continuous gas lift systems comprising numerous wells in a network, however, are typically not modeled by standard gas lift optimization methods. The backpressure impact brought on by wells sharing the network infrastructure presents another challenge.

For instance, a single well analysis method might use the nodal analysis idea to generate a single well using accurate temperature and pressure surveys together with an appropriate multiphase flow correlation. This approach entails separating every well from the others under the presumption of steady wellhead or gathering-system pressures. This assumption might be true in some circumstances, including when wells are choked at the wellhead to maintain stable wellhead pressure, several wells are gathered at the separator to operate under the same pressure system of control, or the pipeline network is predominated by the decrease in pressure across the well's tubing [17]. The cap on gas injection rate is the key restriction in this technique. The limitations of the facilities are not integrated [18].

The equal-slope approach was created by Kanu, Mach and Brown, 1981 and is focused on optimizing profit in continual gas lift systems by weighing liquid output in terms of profit and the injection of gas (compression) in terms of cost. The next step is determining the appropriate allocation rate that maximizes oil production while minimizing the price of gas utilization. According to the equal slope technique's guiding principle, profit maximization will happen when the income from additional oil is equal to or greater than the expense from further gas injection. This method employs a manual process that involves drawing several tangents with identical slopes on every one of the efficiency curves that were previously built at various gas injection rate values [18].

Rashid et al. (2012) described a few optimization techniques that based their conclusions on the Gas Lift Performance Curve (GLPC). These approaches attempted to utilize the GLPC in a way that simultaneously maximizes oil production and minimizes injection costs. Numerous optimization strategies have incorporated financial factors like compression and net profit after deducting injection costs [16]. The linear programming method was used by Fang and Lo, 1996 for allocating injection of gas with a variety of rate of flow restrictions [19]. In the case of when at least two wells share a flow line, the effects of back-pressure are frequently disregarded so that a semi-steady state concept can be taken into account for the solution. For the assessment of a person's well-being, such an approach might be reasonable. When there are flow interactions among wells in the system, coupled well solutions with a surface networks approach appear to be more effective because they take into account the impact of backpressure in the system when distributing gas lift rate [20].

Khamehchi and Mahdiani (2017) and Bergeron et al. (1999) have utilized the Newton Reduction Method in their studies which proved to be faster and more efficient compared to the previous methods. The method faced the problem of fast convergence due to the interdependent wells effect but the results were precise enough [15, 20].

By combining full-network solutions with sequential quadratic programming (SQP), Dutta-Roy and Kattapuram, 1997 created a nonlinear model [21]. Wang and Litvak, 2004 explored using an iterative strategy to tackle the gas lift distribution problem until the network's overall minimum lift efficiency was reached [22].

Nader et. al. (2008) has developed an innovative production optimization model that could revolutionize the way we handle offshore gas fields. Unlike previous approaches, this new model takes into account the entire system, from wells to compressors, providing a comprehensive and holistic view of the complex network. The result is an optimization process that not only maximizes production and reduces costs but also makes the operation more efficient. The model has already been tested in real-world scenarios, demonstrating its ability to increase revenue while cutting expenses [23].

Epelle and Gerogiorgis (2019) built a Real-Time Production Optimization (RTPO) using a robust method based on the Basic-Open-Source Mixed Integer (BONMIN) framework applied to mixed-integer nonlinear programming (MINLP) on a numerical model of the output system while taking into account a number of operational limitations [24, 25].

Researchers have explored various artificial lift optimization methods, including Particle Swarm Optimization, Ant Colony Optimization, and Genetic Algorithm (GA) to address the challenge of gas lift optimization [26].

Hamedi et al. (2011) proposed a novel gas lift optimization method that demonstrated promising results in maximizing oil output while efficiently allocating compressed gas. The method incorporates a particle swarm optimization algorithm that allocates the ideal gas injection rate for each well within a group, along with a new gas lift performance curve-fit method that significantly reduces computation time and gas volume. These improvements are particularly significant in gas lift operations, where compressed gas is a scarce and expensive resource [27].

Ghaedi et al. (2014) proposed a Continuous Ant Colony Optimization (CACO) algorithm to allocate an optimal amount of gas to each well within a group for three different oil fields, each with a varying number of wells. A comparison between the total oil production rates resulting from gas allocation to the wells using the CACO algorithm and previous studies utilizing other methods reveals that the CACO approach achieves superior gas allocation to the wells [28].

Numerous academics have examined the Genetic approach (GA) [9], the approach we choose to apply in this study, and its application to the problem of gas lift optimization. Martinez *et al.*, 1994 were one of the first investigators who utilized the GA algorithm to address the issue of gas lift optimization, and the outcomes of the research showed that the mathematical method that was utilized proved to be effective [29].

Ray and Sarker (2007) proposed modifications to the Genetic Algorithm and the formulation of gas lift optimization problems as multi-objective models that offer improved performance in solving these complex optimization problems. By treating reservoir optimization as a multi-period problem, this research also provides a methodology for generating flexible production plans that better reflect the dynamics of oil extraction over time. Furthermore, the population shrinking technique incorporated in the GA enables the maintenance of diversity in both objective and variable space, which results in more robust and effective solutions to gas lift optimization problems [30].

Khamehchi et al. (2009) used the genetic algorithm to build and improve the efficient aspects while taking into account the (injection pressure and water cut) as a constraint in order to achieve the highest production rate [31].

AlJuboori et al. (2020) investigated the feasibility of using the Genetic Algorithm (GA) technique to optimize the continuous gas-lift injection rate allocation in a network system of a Middle Eastern oil field with 43 gas-lift injected wells. This research conducts reservoir pressure and water cut sensitivity studies to assess the impact of these parameters on well performance and production life cycle. Furthermore, sample economics analyses are performed to examine the potential technical and economic benefits of implementing gas lift techniques in the field [9].

Al-Janabi et al. (2021) this work focuses on applying the Genetic Algorithm (GA) as a gas lift optimization algorithm to the difficult problem of maximizing the oil production of a Middle Eastern oil field with 20 production wells and a finite amount of gas to be injected. This is done through numerical modeling and simulation studies to optimally allocate the gas lift injection rate [32]. Ahmed et al. (2023) examined the effect of gas lift design and optimization on production results in the Mishrif formation of the Halfaya oil field. A detailed production network nodal analysis model was constructed using PIPESIM Optimizer and field data from seven wells, with the model being calibrated to accurately reflect the field conditions. The Mishrif Formation in the Halfaya oil field is one example of a complicated reservoir system. This research highlights the importance of strategically designed and optimized gas lift systems for improving oil recovery and operating efficiency. The achievement of these ideal parameters was made possible by the application of the PIPESIM Optimizer, which is based on the concepts of genetic algorithms [33].

The earlier described optimization techniques might only be effective under very specific conditions. Due to the lack of consideration for back pressure and the challenges associated with integrating facility and production restrictions, these conventional techniques are not well suited for handling wells that are part of the same network system. Using these methods to describe and simulate a big network system accurately is quite difficult because it takes a lot of calculation time and frequently yields false results. Another aspect of poor solutions is locating a local answer to the issue. Consequently, using dynamic global algorithms may be required to address these problems, as suggested by Buitrago et al. [34], they offered derivative-free algorithms that implemented a heuristic method for distributing gas lift while resolving the crucial problems of non-instantaneous flows (NIF) and unsmooth curvature for a significant number of wells. In order to properly integrate all of these restrictions of gas lift difficulties, the Genetic Algorithm, or GA, optimization is the main emphasis of this study on improving the gas lift.

In our study, the genetic algorithm (GA) as an optimization algorithm a network simulator is utilized using the PIPESIM software in order to construct the model with the available 10 production wells in the field and we created a new model for matching PVT information, matching calculations for vertical pressure drops, making sensitivity analyses (water cut sensitivity and reservoir pressure sensitivity) of productivity index and wellhead temperature variations, achieving the best gas lift design, and determining the best values for injected gas rate and production of oil.

2- Genetic Algorithm

In addition to using natural selection to solve optimization problems, the genetic algorithm is based on the principles of genetic recombination processes, which include the main purposes of selection, crossovers, and mutation. Holland, 1992 was the first person to introduce the genetic algorithm, or GA, concept to solve both constrained and unconstrained optimization problems through the method of natural selection centered upon Darwin's theory of the fittest function and the fundamental ideas of evolutionary science [35].

Due to the fundamental distinction between the genetic algorithm, or GA, and other conventional methodologies, it was regarded as one of the most recent methods of optimization. The majority of GA solutions are global optimums because GA employs a population of chosen points to avoid the optimal local solution [36]. Discrete and integer problems are extremely suited to be addressed by GA since the genetic algorithm depicts the chosen variables by utilizing a sequence of binary integers (0,1) for imitating the chromosomes in genetics [37, 38].

The imitation of biology in the application of the GA led to the importing of several terms and defections from biology to the applications like: (population, generation, gene, chromosome, mutation, and crossover) and to be able to fully understand the process a well-established knowledge of the terminology is required [39].

- The Gene, the smallest building block in a string (individual) of GA, is made up of the binary values (0,1) that stand in for every parameter (variables) in the assembled chromosomes.
- Chromosomes are a long string of numbers that are produced when numerous genes are combined to form an individual; each individual represents a potential solution to the current issue because it is denoted by a value that is numerical. And as observed by Ray and Sarker [30].
- The population is represented by the collection of solutions (chromosomes), and the population size identifies the quantity that distributes the gas lift rate [30].
- The Fitness Function may be described as a score of how physically fit an individual was and their capacity to compete with one another. This can be accomplished by assigning each candidate a fitness score, and candidates will be chosen based on that number. The task that the GA seeks to optimize is known as the fitness function, and in the context of gas lift, this function refers to the oil flow rate that the method of optimization seeks to maximize [40].
- The selection is the procedure of identifying the fittest chromosome (individuals) and evaluating them in terms of fitness function, allowing those with the greatest fitness ranked to have the greatest possibility of being the parents who produce new offspring (children), while those with the smallest fitness value have the lowest probability [40].

The most important step in the GA is crossover, which involves mating every pair of individuals who were chosen as parents in the selection step by switching their genes at one or two points of crossover in order to recombine the chromosomes and create the new offspring (generation) [41]. Three different types of crossovers exist.

- Single Point Crossover
- Double Point Crossover
- Uniform Crossover

The crossover between two good individuals will not always produce a better individual but as the parents are good (selected based on high fitness rank), the child will have a high probability of being good, and in the case of offspring not being good enough they will be distant in the next selection.

- The GA operator known as mutation maintains diversity. It is a low-probability step that results in the flipping of a few random genes on the newly formed spring chromosomes. The mutation probability can range from zero (no mutation) to one (mutation after each iteration). The mutation process plays an important part in keeping a population's variation, and although it prolongs the convergence process, mutation prevents premature convergence. In the event that the initial population missed certain areas of the solution that haven't been attained by both the selection and crossover steps, mutation provides the probability. As a result, utilizing mutation allows GA to reach a better conclusion [40].
- When the population as a whole does not create new children (offspring) who are distinct from previous generations (the population has converged), we have reached the phase known as termination. This occurs when the genetic code solves the problem by offering a set of answers [32].

Gen and Cheng (1999) provided an example of how conventional procedures, which employ a single-point answer and a deterministic sequencing of a derivative-based objective function, mostly provide local optimum solutions. The population-based GA solution will avoid sliding into the local optimum by maintaining multipoint to multipoint approaches for each generation. In this strategy, the likelihood of the best, most fit solution outlasting the least fit one is higher. Therefore, the GA will typically produce a global optimum outcome [36].

According to Sarker et al., 2003, GA provides the following advantages over traditional optimization techniques for modeling gas lift method optimization problems [42]:

- Unlike other optimization techniques, GA does not require assuming the concavity, convexity, or continuity of the algorithm.
- GA can incorporate some established techniques, such as the hybrid algorithm, to increase its effectiveness in resolving the constraints present in gas lift situations.

- GA may provide multiple-point solutions, such as the first, second, third, etc., but conventional approaches can only provide the most suitable single point answer. This feature is particularly important for decision-makers in the oil field sector because some of them might need to consider other potential options. GA can provide three of the best options for deciding the gas lift technique's optimal solution; each of these can be tailored to the choice maker's goals.
- GA has the ability to integrate the function of penalties while answering all optimization problems according to constraints by recommending a change to the structure to provide a workable solution that satisfies the multicasting objective functions;
- Compared to a traditional technique, GA typically offers a quicker answer to an optimization challenge. Even occasionally, a brief approximation solution requires a small generation [43].
- A crucial consideration in selecting this method for resolving the gas lift optimization problem is the ability of GA to resolve multi-objective or multivariate optimization problems because it is advantageous in that it offers a variety of options in a single simulation run while also taking into account gas-lift constraints like the water supply and gas handling system, flowing bottom well pressure, and the gas injection rates [32, 44-46].
- The starting point solution is created randomly in this method without the inclusion of any technique, which reduces the time required to get the starting point solutions and the amount of work required to provide the initial point data to start optimization.
- In The objective function may need to be adjusted in the oil sector due to the ongoing changes in oil wells and field data, particularly production data for each well like GOR, water cut, and oil flow rate. In this situation, GA can easily handle such an adjustment and offer the best option.

Five fundamental phases make up GA techniques: starting population, fitness function, selection, crossover, and mutation.

Initial population is the first step in the process and consists of a group of individuals (i.e., solution) inside the search space. An individual is defined by a variety of combinations of the "genes," which are put together to form the chromosome (or solution) and are referred to as design variables (or parameters). A determination of each solution's objective function, a measure of fitness, is made. A mating pair, which is utilized to reproduce future populations, is created by pairing each solution with another. Through the crossover of the values of the parents, the mating pairs create new solutions called offspring that have the value of the design variables. Additionally, some of the values in the new solution undergo random mutation. The vast range of factors can be evaluated with the help of mutations, which can delay the onset of convergence. Although its optimization allows for one solution to define the level of control, the GA technique's procedure is random. The steps for applying the GA approach to model the gas lift problem are outlined below:

1. Creation of the first population: As seen in Fig. 1, lifting gas injection rates are regarded as chromosomes, and 4 chromosomes (A, B, C, and D) are produced with the gas injecting rate specified [9].
2. When evaluating fitness function, oil flow rate—which depends on lift gas injection rate—is taken into account.
3. The optimization process is completed if the results satisfy the optimization requirements.
4. In the absence of this, the solution is changed by choosing two chromosomes.
5. performing crossover for each pair of chosen chromosomes with a probability lower than the crossover threshold.
6. Chromosome mutation, if necessary to create a new generation.
7. Calculating the standard deviation of the values for fitness of new generations.
8. If there is no restriction on the total number of new generations, the problem is solved iteratively until the best answer is obtained.

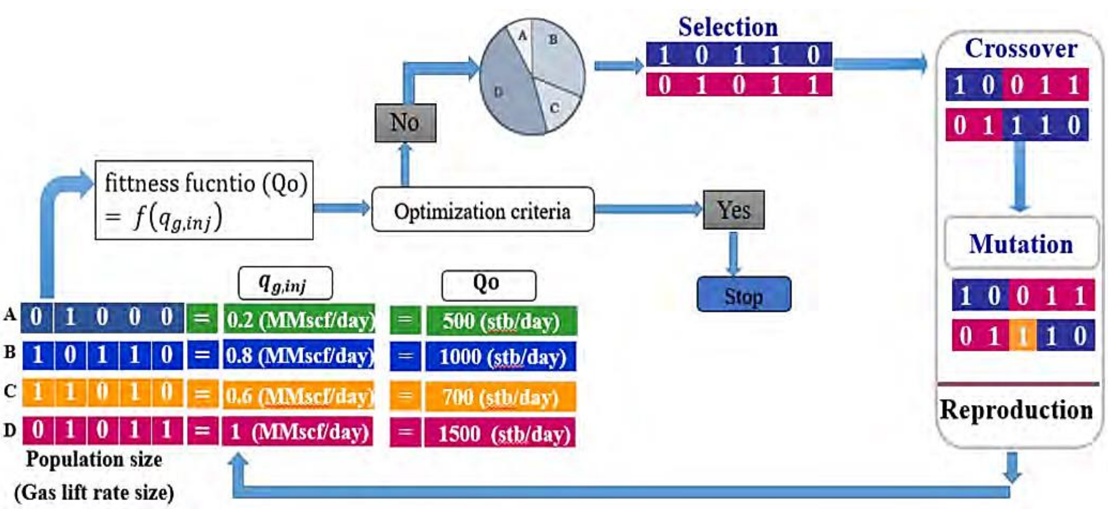

Fig. 1. The Workflow of GA to Obtain the Optimum Results [9]

3- Numerical Modeling and Simulation

The implementation of the GA method in a real case can effectively assess its power in modeling the problems of gas lift well considering all numerical simulation constraints being discussed above to find the feasibility of the use of such technique on a daily basis in the oil fields. This work vastly involves modeling and numerical simulation for the Zubair oil field using the GA-based optimization tool. The model considered 10 wells of this field, each of which is being installed with a gas-lift injection system in a network. GA uses the survival of best solution principles depending on generating the initial solutions, finding the results, selecting the best solutions of multi-objective and multi-constrained functions, and improving the solutions to obtain the optimum result.

4- Field Background

The Zubair oilfield is 20 kilometers southwest of the Al-Basra city in southern Iraq. It was discovered in 1949, and development began in 1951. Anticline (60 × 15 km) is the field's shape, and it has three domes (after combining Hammar and Shuaiba into one dome): Hammar- Shuaiba, Rafydia, and Safwan. The producing layers are situated at around a depth of (2250, 3100, 3180, 3360) m with initial reservoir pressure around 5400 psi. This field consists of three reservoirs: third pay, fourth pay, and upper shale. The third pay reservoir in the Zubair formation will be taken into consideration for this study; it is composed of sandstone and is located at a depth of 3180 meters. This field has a number of gas lift wells to keep the reservoir pressure. Deep wells approximately 3200 meters deep with a depletion drive mechanism cause the reservoir pressure to drop very quickly, which lowers oil production rates and increases water cuts in some wells. As a result, attention is drawn to the gas lift method with the goal of maximizing oil production due to the decrease in average pressure in the reservoir and well performance.

5- Well Flow Model

Building a numerical simulation model is usually incredibly difficult because of the lack of necessary data, especially when the model is meant to represent the entire area. It might be difficult to accurately determine the flowing bottomhole pressure (P_{wf}), perform pressure-volume-temperature (PVT) investigations of reservoir fluids, discover matching PVT correlations, and determine the outflow performance (VLP) correlation for the wells. According to the PVT measurement experiments of wells in this field, the field PVT data derived from lab data are taken into consideration as a median for the entire field, especially as the disparity between them appears to be minor based on the lab data. Second, the data was further calibrated using the fluids in the reservoir of Zubair Oil Field after matching the PVT data with appropriate correlations. The precise measurement of the gas compressibility factor is a prerequisite for the exact computation of all gas properties, including viscosity, gas density, and gas formation volume factor Additionally, since pressure and temperature have a significant impact on the compressibility of gases, it is difficult to find a correlation that can be used across the entire pressure and temperature spectrum [47]. The wellhead pressure, oil production rate, and a few test points were compared to the production data that was provided. The secret to performing a precise nodal analysis is finding the matching multiphase flow correlation [48]. Therefore, the bottom hole flow pressure, P_{wf}, is computed using multiphase correlations utilizing the production data that is now available and the PVT parameters. The PIPESIM simulator then used the generated P_{wf} data to establish the best history-matching tubing flow correlations. It is interesting to note that Zubair Oil Field's matching flow correlation was found to be different. For vertical flow, Hagedom & Brown and Beggs & Brill updated correlations that are closest to the available test points (measured data) are the best. For horizontal flow, Beggs & Brill modified correlations are the best.

6- Building Well Model

In order to construct the well model, numerous well characteristics must be defined, including fluid properties, perforation, casing and tube information, PVT data, and perforation test point information. It has been discovered that these data vary from well to well. Model schematic after construction using the PIPESIM simulator is shown in Fig. 2. The location, type, casing information, perforation features, tubing size, nodal point, line of flow diameter and temperature, and wellhead pressure are all entered before the well model is built. By adding this data, a well model is created, which is then history-matched in order to get ready to simulate the field's gas lift performance.

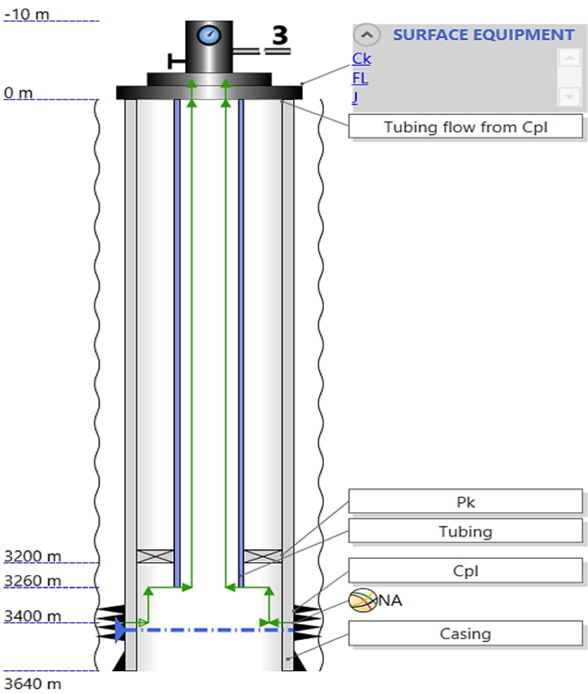

Fig. 2. A Well Schematic (Well-ZA) After Being Built by Simulation

7- Gas Lift Design Data

The associated gases, which are produced in the same field as the oil, is thought to be the source of the gas injection. According to reports, this field produces gas at a rate of 33 MMscf per day on average. Initially segregated through a separator, the associated gases are then processed, gathered, and recycled once more by being injected back into the oil wells. According to completion programs, 3.5″ tubing is used to complete every well. According to Al-Fatlawi et al., 2015 the functioning gas lift valve is positioned 100 feet above the packer. According to the field data, the temperature at the surface is about 115°F. To ensure a single-phase inflow into the well, a minimum P_{wf} of 50 psi over the point of bubble pressure (P_b) is assumed [2]. Additionally, the PIPESIM simulator contains a gas lift valve bracketed function or error envelope that enables the modeling of an extra equal space valve at the conclusion of the indicated operational valve to accommodate any design fault [32, 49]. This plan helps to resolve any ambiguity in the gas lift design by accounting for any error in the flow's multiphase correlation in both the vertical and horizontal directions, as well as any uncertainty in a well's productivity index, as shown in Fig. 3.

Fig. 3 shows the proposed design for a well with a gas lift and activated bracketing feature.

Laing, 1991 provides support for this claim by implementing this characteristic in two oil fields, which increased oil production and enhanced well performance. Additionally, a flexible design that can account for unexpected or low well productivity index is already taken into consideration [50].

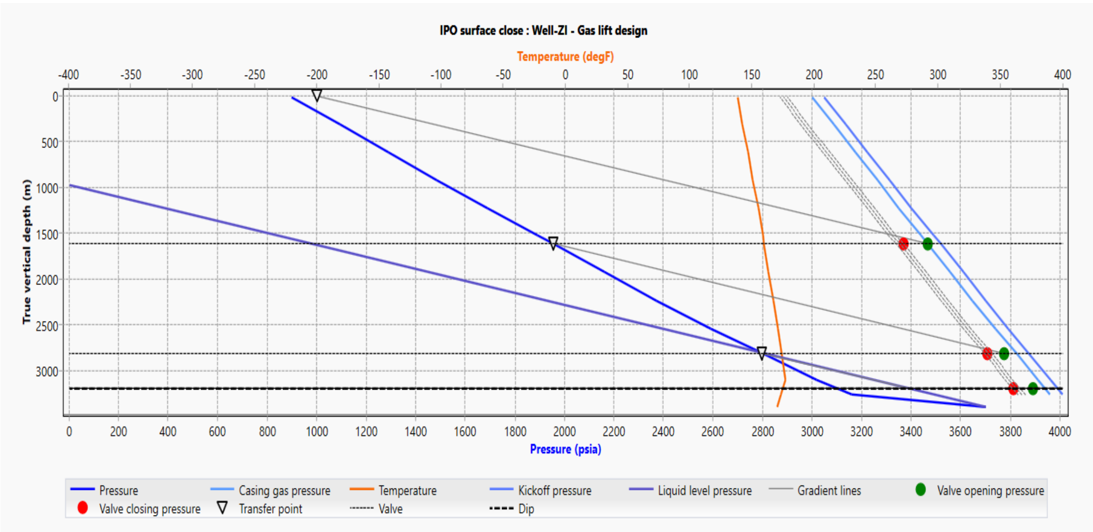

Fig. 3. Depicts the Proposed Gas Lift Design for the Production Well, with the Bracketing Function Enabled

8- Building Field Model

The surface network simulation is constructed using the PIPESIM simulator when the well modeling is complete, as illustrated in Fig. 4. Ten producing wells are part of the network model, and they are all taken into account for gas lift optimization utilizing the GA approach in order to spread the gas injection across the network's wells as efficiently as possible.

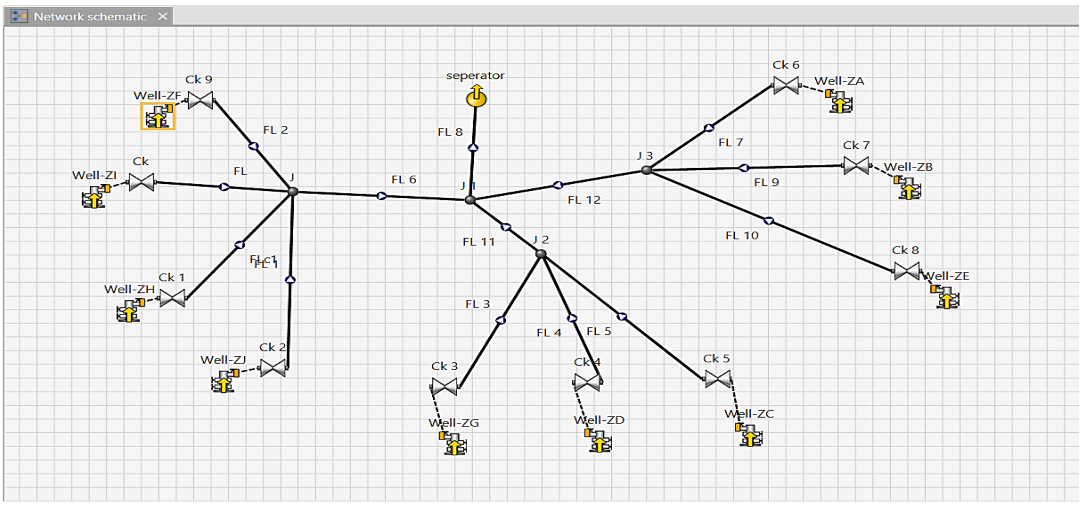

Fig. 4. The Network Wells Are Clearly Visible

9- Sensitivity Analyses

Sensitivity assessments were conducted to examine the potential effects of changing reservoir pressure and water cut upon the functionality of natural flow and gas lift wells, particularly over the long term when reservoir pressure is expected to decline and water cut to rise.

9.1. Water cut sensitivity

In order to look into the impact of water cuts on both the well and field performance, water cut sensitivity experiments were carried out for both natural flow and gas lift wells. In this analysis, several water cuts that range from 10% - 50% were taken into account. In order to contrast the good behavior in every instance without favoring any particular procedure, the sensitivity analysis was carried out for each well after and before the use of gas lift at the exact same wellhead pressure.

9.2. Reservoir pressure sensitivity

The goal of the pressure in the reservoir sensitivity research was to ascertain how reservoir pressure depletion might affect the good performance profile; identify its potential influence in the field production life cycle for both natural flowing and gas lift wells; and investigate whether the gas lift wells can have any positive influence in relation to the improvement of good performance in the case of reservoir pressure depletion. The average reservoir pressure considered for the sensitivity studies were 3500 psi, 3250 psi, 3000 psi, 2750 psi, 2500 psi, 2250 psi, 2000 psi, 1750 psi, 1500 psi, 1250 psi, and 1000 psi for a given minimum wellhead pressure of 250 psi. The wellhead pressure of 250 psi is assumed to be the minimum pressure required to support the surface system requirement (e.g., separator system).

10- Results Analysis and Discussions

10.1. Simulation results

Both naturally flowing wells and continuously lifting gas wells were simulated. GA method is used to optimize gas lift performance at a 33 MMscf/day maximum gas lift injection rate. The simulation results for naturally flowing wells and gas lift wells compared in Fig. 5 demonstrate that there is a significant increase in oil production rate (% of the increase in oil production) from each well for this field as compared to natural flowing wells. The overall increase of filed production rate is found to be increased from 15767 STB/day to 19847 STB/day.

In order to compare the effect of the optimization technique, Fig. 6 will provide a comparison between the two cases before and after the optimization to show the difference in the distribution of the gas injection rate for every well and the effect that increased the oil production from (17242 STB/day) in the case of before optimization to (19847 STB/day) after the use of the optimization algorithm.

The results will show the importance of applying the optimization technique to the gas lift process and using a multi-constrains algorithm is highly important to be able to handle all the different constraints especially when working with a large number of wells and for the case of the limited amount of injection gas in order to achieve the best production rate with the available gas in hand.

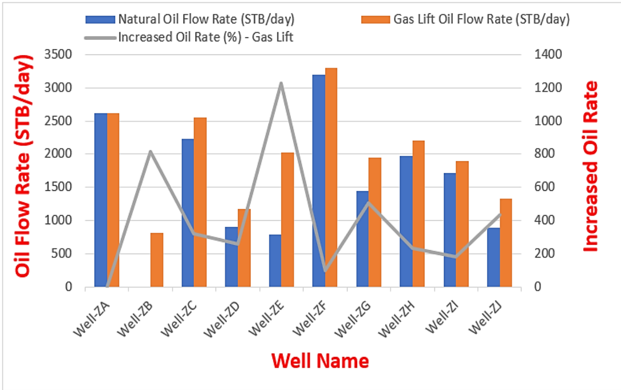

Fig. 5. Comparison between the Production of Natural Flow Wells and the Gas Lifted Wells

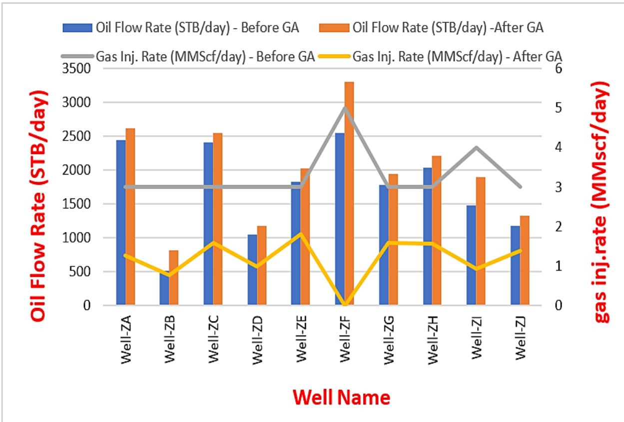

Fig. 6. Comparing the Results of Gas Lift Before and After the Optimization

Before the optimization work, we noticed that Well-ZF required the pumping of 5 MMscf/day gas into it, and its production was 2500 STB/day. However, after the optimization technique, we discovered that it no longer requires the pumping of gas, and despite this, its oil production increased to 3300 STB/day as a result of the neighboring Nearby wells, because when a gas lift was made, it eliminated the negative effect of the Nearby wells on it in the network system.

10.2. Water cut sensitivity results

Fig. 7 shows the findings of a study on water cut (WC) sensitivity for 10 oil wells that were both naturally produced wells and gas-lifted wells. Fig. 9 confirms what was predicted, showing that for natural flow and gas lift wells, the rate of oil production falls as the water cut (WC) increases. Fig. 7 also shows that the increased WC necessitates a greater gas lift injected rate. However, it appears that the use of gas lifts has greatly increased the pace of overall oil production. It is discovered that the use of gas lift results in a very significant overall output boost, particularly at a greater water cut.

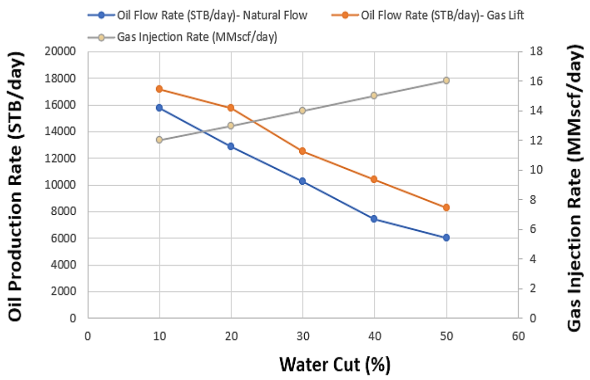

Fig. 7. Results of Water Cut Sensitivity

10.3. Reservoir pressure sensitivity results

The goal of the reservoir pressure sensitivity study was to ascertain the minimum average reservoir necessary for a well to stay productive as well as to evaluate the impact of lowering reservoir pressure on the efficiency of 10 oil wells. This sensitivity begins at the present reservoir pressure of approximately 3500 psi and continues until it reaches the pressure value where both oil-producing wells and gas lift wells are unable to flow. In the beginning, nodal analysis was done at various reservoir pressures to figure out the average minimum reservoir pressure needed to maintain production at the specified wellhead pressure of 250 psi for all cases.

The mean reservoir the pressure at which a well will shut down for both of the cases of naturally occurring flow and gas lift, which can identify the improvement of sensitivity caused by applying the various types of artificial lift, is shown in Table 1, respectively. From Table 1, it is evident that most wells in a natural flow condition will typically shut down at (3187 psi) on average. On the other side, we can observe that the gas lift approaches were successful in lowering the operating pressure in the reservoir and those wells will continue to operate. For the gas lift method, the average pressure at which the wells are going to shut down is (586 psi). Gas lift may be viewed as an important justification for using methods of lifting to maintain pressure because wells remain able to flow out under lower pressures if the pressure in the reservoir is reduced.

Table 1. Reservoir Pressure at which the Well Shuts Down for Each Case

Well Name	Natural Flow (psi)	Gas Lift (psi)
Well-ZA	2950	572
Well-ZB	2396	572
Well-ZC	3259	571
Well-ZD	3082	571
Well-ZE	2600	573
Well-ZF	5100	607
Well-ZG	2990	571
Well-ZH	3137	607
Well-ZI	3700	607
Well-ZJ	2655	607

To be able to visualize the difference in the results of the pressure sensitivity a graphical illustration of the effect of the gas lift method on maintaining the production of the wells even in the cases of reservoir pressure reduction can be seen in Fig. 8 which represents the outflow performance of the wells against different values of reservoir pressure which can then help to identify the well operation point.

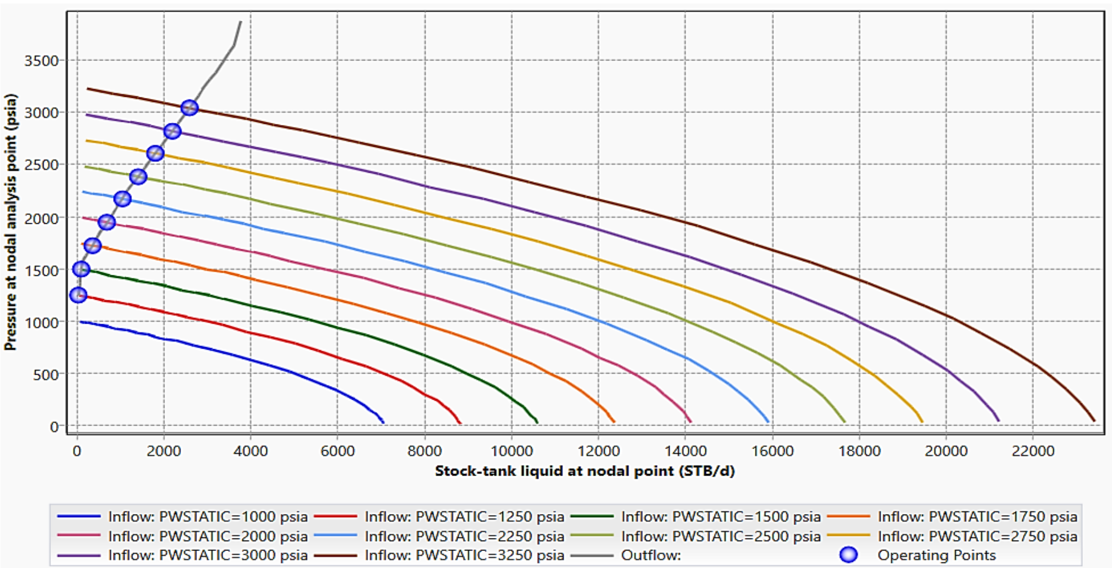

Fig. 8. The Effect of Changing the PR for a Well Installed with Gas Lift

The results indicate that wells equipped with a gas lift continue to produce at relatively high rates despite low reservoir pressures, confirming the gas lift economic utility in sustaining high rates of production for many years.

11- Economic Analysis

To determine whether applying the gas lift optimization method in the real world would be profitable, economic analysis was used. From Nakashima and Camponogara, 2006, the equation employed in this analysis is represented by Eq. 1 [51]. Oil and gas prices of $55 per STB and $5,500 per MMscf, respectively, were used as the basis for the analysis. According to Huh *et al.*, 2010, the costs associated with disposing of water, running a gas lift, and other operations are each estimated to be $1 per barrel of water, $3,500 per million standard cubic feet, and $8 each STB produced well [52].

$$Net\ Profit = \sum_i^n [q_{oi}\,(p_o - c_{op}) + (p_g \times q_g) - (q_{wi} \times c_{wi}) - (Q_{gi,inj} \times c_{g,inj})] \quad (1)$$

Where: n: The Total Number of Wells. q_{oi}: Rates of Oil Production (STB/day). q_g: Rates of Gas Production (MMscf/day). q_{wi}: Water Production Rate (STB/day). $Q_{gi,inj}$: Lifting Gas Injection Rates (MMscf/day). p_o: The cost of oil ($/STB). c_{op}: Operational Costs ($/STB) for each STB of oil. p_g: Gas Price ($/MMscf). c_w: Cost of disposal of water ($/STB). $c_{g,\ inj}$: Cost of lift gas injection ($/MMscf)

Applying the above prices in Eq. 1 would result in a net profit of (1269475 $/day) for the gas lift case compared to a value of (934576 $/day) for the case of natural flow which is considered a great profit and a great value provided by the increase of production from the gas lift case, it's worth mentioning that in the case of natural flow the equation was modified to remove the term of the gas injection rate and it is price.

seeing the outcomes of the OPEX estimates for the two instances of natural flowing and gas lift to make it easier to compare the various outcomes, Fig. 9 is intended to show the oil production rates for every well in each instance as well as the net profit of every well in each case.

Fig. 9 compares the daily net revenue without or with gas lift as well as the total increase in the daily crude oil production rates for 10 wells. According to the computed results, the gas lift method can significantly raise each well's daily oil production rates and, consequently, its net profit when compared with naturally producing wells.

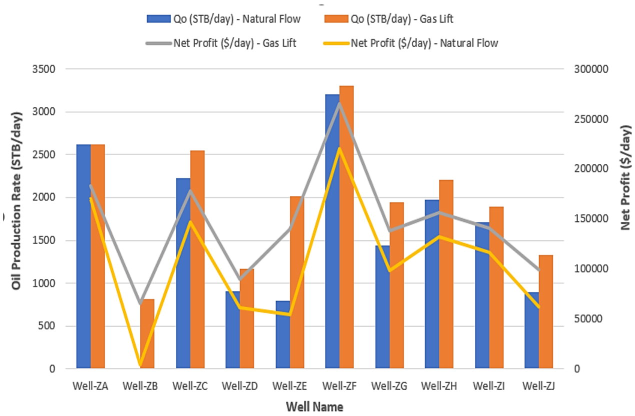

Fig. 9. Natural Flowing and Gas Lift are Compared with Flow Rate and Net Profit

12- Conclusions

The main goal of this paper was to determine whether using a GA-based optimization strategy in numerical simulation for daily optimization of gas lifting wells in a large field with a complex network structure was feasible. Using numerical simulation and the GA approach, one of the massive Middle Eastern oilfields' continuous lifts of gas injection rate is optimized over 10 wells. This paper includes a thorough discussion of the GA principles, the mathematical model, as well as the process for carrying out simulation investigations.

Through the presentation of optimization and sensitivity analyses, the study also provided insight into future prediction and expanded understanding from both a technical and economic standpoint. An example economic analysis was also carried out to shed light on the benefits of employing gas lift techniques in depleting drive reservoirs, especially in the event of an increasing water cut and severely low reservoir pressure.

The study's findings lead to the following conclusions:

- The optimal way to distribute gas injection rates for maximizing oil production rates appears to be predicted using genetic algorithms, or GAs, for modeling many of the concurrently running wells into a system of networks.
- For wells with relatively greater water cuts, gas lift procedures prove to be more advantageous.
- In the event of pressure depletion in the reservoir, gas lift can be helpful in extending the field's life cycle and enhancing well production performance by enabling a well to continue operating at even low flows the wellbore bottom hole the pressure (P_{wf}) that it is designated minimum wellhead pressure.
- The sample economic analysis shows that, compared to the use of natural wells, the gas lift approach can significantly boost each well's daily crude oil production rate and, consequently, its net profit.

Acknowledgment

The authors are grateful to Schlumberger Company for approving their use of the PIPESIM academic simulator.

Nomenclature

AI	Artificial Intelligence
GA	Genetic algorithm
GLPC	Gas lift performance curve
IPR	Inflow performance relationship
OPEX	Operational Expenditure
PI	Productivity index
P_{wf}	Bottom hole flowing pressure
P_{wh}	*Well Head Pressure*
$q_{gi,inj}$	Gas lift injection rate, Mscf/day
q_o	Total oil production, STB/day
q_{oi}	Individual well oil production rate, STB/day
SQP	Sequential quadratic programming approach
VLP	Vertical lift performance

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عملية الرفع بالغاز لتحسين حقل الزبير النفطي باستخدام المحاكاة العددية القائمة على الخوارزمية الجينية: دراسة الجدوى

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الخلاصة

تعتبر طريقة رفع الغاز ضرورية للحفاظ على إنتاج النفط، خاصة من الحقول الحالية عندما يتم استنفاد الطاقة الطبيعية من المكامن. لزيادة إنتاج النفط، يجب توزيع معدل حقن الغاز في الحقل الرئيسي بأكبر قدر ممكن من الكفاءة عبر نظام شبكي لعملية رفع الغاز. قد تفقد تقنيات تحسين رفع الغاز الشائعة فعاليتها وتصبح غير قادرة على تكرار رفع الغاز الأمثل في نظام شبكة كبير بسبب مشاكل في توزيع معدل حقن الغاز متعدد الأهداف والمقيد؟ الهدف الرئيسي من البحث هو تحديد إمكانية استخدام تقنية الخوارزمية الجينية (GA) لتحقيق التوزيع الأمثل لتدفقات حقن الرفع الغازي المستمر في هيكل شبكة حقل الزبير النفطي الذي يضم ١٠ آبار حقن الرفع الغازي. وسيتم ذلك من خلال دراسات المحاكاة والنمذجة العددية. تم العثور على الزيادة الإجمالية في معدل الإنتاج المقدم من ١٥٧٦٦ ستب / يوم إلى ١٩٨٤٧ ستب / يوم. يتم إجراء دراسات ضغط خزان البئر وحساسية قطع المياه لدراسة التأثيرات المحتملة لهذه العناصر على البئر وكفاءته من خلال مجرى الحقل. يتم تعميق فهمنا للفوائد المحتملة لاستخدام تقنيات رفع الغاز في الحقل من وجهة نظر فنية واقتصادية من خلال استخدام أمثلة من التحليل الاقتصادي. علاوة على ذلك، على الرغم من أن فكرة استخدام GA بهذه الطريقة ليست جديدة، فإن هذا العمل يناقش منهجيات التحسين المستندة إلى GA لزيادة معدل إنتاج النفط باستخدام رفع الغاز في حقل نفط الزبير. من أجل تعيين معدلات حقن الغاز لآبار محددة في شبكة في جميع أنحاء الحقل باستخدام معدلات حقن غاز محدودة، سيتم وضع نموذج التحسين خطوة بخطوة مما يسهل فهمه واستخدامه كدليل، خاصة لفنيي الإنتاج في الخطوط الأمامية المشاركين في تطوير وتصميم أنظمة رفع الغاز.

الكلمات الدالة: تحسين رفع الغاز، رفع الغاز، محاكاة رقمية، الخوارزميات الجينية، حقل الزبير النفطي.