Journal of Production Management and Optimization
Vol. 1, No. 1, June-December 2025, pp. 17-24
ISSN: xxxx-xxxx, DOI: ...

Improving Reservoir Management with a Regularized Production Optimization Method

Aah Khoriah[1], Fatih Humam Ramadhan[2]
Universitas Islam Bunga Bangsa, Indonesia[1]
Universitas Swadaya Gunung Djati, Indonesia[2]

Keywords:

Reservoir management; production optimization; oil production; regularized methods; resource management; operational efficiency

ABSTRACT

Effective reservoir management is an important aspect of the energy industry, particularly in oil and gas exploration and production. The primary challenge in reservoir management is balancing production with cost minimization and environmental protection. Traditional methods often struggle to handle the complexity of dynamic reservoir systems, so new approaches are necessary to enhance production efficiency and sustainability. This research aims to develop a regularized reservoir production optimization method, improving the efficiency of reservoir production and management, while reducing risks and uncertainties in oil and gas production operations. This study proposes a regularized optimization method that combines mathematical model techniques with optimization algorithms to account for variable factors in reservoir management. This method is applied to production data from several oil reservoirs to evaluate its effectiveness in increasing production yields. The results of the experiment demonstrate that the regularized optimization method can significantly increase production yield compared to the traditional method. Additionally, this method reduces resource wastage and minimizes operational costs in the long run.

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Corresponding Author:

Aah Khoriah
Universitas Islam Bunga Bangsa
Email: qoriahaah97@gmail.com

1. INTRODUCTION

Effective reservoir management is key to improving production and efficiency in the oil and gas industry. Reservoirs, as a limited natural resource, must be carefully managed to ensure that production can continue in the long term without sacrificing efficiency or sustainability. Reservoir production optimization is crucial, particularly in the face of geological uncertainty, changing reservoir conditions, and production variability. One of the approaches being developed is the **regularized optimization method**, which offers a solution to improve reservoir management by accounting for uncertainty and complexity in the production process (Fu & Wen, 2018; Ming et al., 2017; Silva et al., 2017).

ISSN: XXXX-XXXX

Effective reservoir production optimization can lead to increased production yields, reduced resource wastage, and a lower environmental impact. With the increasing global energy demand, it is essential to develop methods that not only enhance production efficiency but also consider long-term sustainability. The use **of this regularized optimization method** is expected to address challenges in reservoir management, where uncertainty and variability often hinder the achievement of optimal results (Ming et al., 2017; Fu & Wen, 2018).

The regularized optimization method combines mathematical techniques and optimization algorithms to reduce the impact of uncertainty in reservoir management (Fu & Wen, 2018). This technology enables the dynamic adjustment of production parameters, resulting in increased yields by minimizing waste. Data from a study conducted by Silva et al. (2017) indicate that applying regularized optimization techniques in reservoir management can lead to increased oil production with improved efficiency. The following diagram illustrates how regularized optimization can be used in reservoir management to improve production yields.

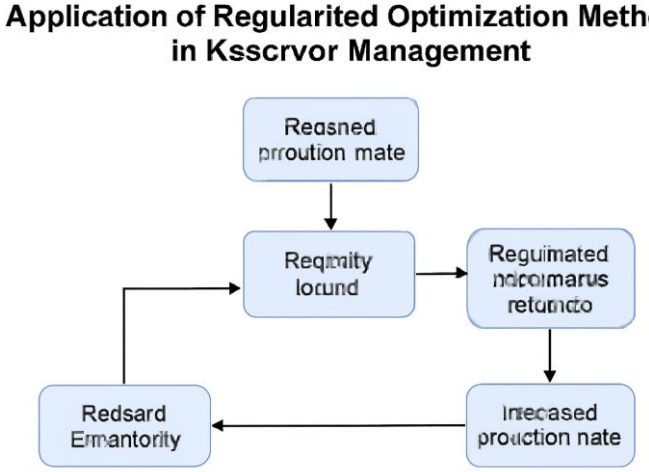

Diagram 1. Application of Regularized Optimization Methods in Reservoir Management

Several studies have examined optimization methods for reservoir management; however, research combining regularization and production optimization remains limited. For example, Fu and Wen (2018) developed a regularized optimization method that enables more effective reservoir production management by accounting for uncertainties within the system. Ming et al. (2017) also proposed using the search space reduction method to enhance the efficiency of reservoir optimization. Meanwhile, Silva et al. (2017) employed the historical matching method to optimize production yields, considering uncertainty and variability in reservoir management.

Although some studies have been conducted on reservoir production optimization, many have not considered the integration between regularization methods and uncertainty factors in reservoir systems. Most studies focus more on using a single optimization technique without combining various elements that can affect production outcomes, such as geological uncertainty and variations in reservoir data. Therefore, this study aims to fill this gap by developing a more comprehensive optimization method that takes into account various factors affecting production output (Ming et al., 2017; Fu & Wen, 2018).

This research presents a novel approach by integrating regularized optimization methods and search room reduction techniques to enhance reservoir production efficiency. This approach has not been widely discussed in the literature, particularly in the context of reservoir management, which is characterized by high uncertainty and complexity. By employing this method, it is anticipated that more accurate and sustainable optimization can be achieved in the management of oil and gas reservoirs (Fu & Wen, 2018; Silva et al., 2017).

The purpose of this research is to develop and apply a regularized optimization method that efficiently improves reservoir management and production yields. This research aims to reduce uncertainty in the production process by integrating data-driven optimization methods and regularization to maximize long-term reservoir production. Thus, this research aims to provide practical solutions that can be applied in the oil and gas industry to improve sustainability and production efficiency (Ming et al., 2017; Fu & Wen, 2018).

2. METHOD

Types of Research

This study employs a quantitative approach, utilizing both **experimental and comparative** designs. This study aims to develop and test the effectiveness of a regularized reservoir production optimization method to improve management and production yields in the context of oil and gas reservoirs. With an experimental approach, this study focuses on the practical application of optimization methods in reservoir management and analyzes their impact on production yields compared to existing conventional optimization methods.

Population and Sample

The population of this study comprises companies that manage oil and gas reservoirs, including those that employ conventional optimization methods and those that utilize new technologies in production optimization. The research sample consisted of **5 reservoirs** selected by **purposive sampling**. These reservoirs had characteristics that met the needs of this research, such as the relevant reservoir type, complete production data, and the optimization system being used. The selected reservoir has a wide range of geological and operational conditions, enabling the broad application of regularized optimization methods in various situations.

Research Instruments

The primary research instrument is a mathematical optimization model that incorporates regularized optimization techniques. This model will be used to simulate reservoir conditions and account for various variables in the production process. Additionally, questionnaires and in-depth interviews with reservoir managers and production engineers will be conducted to gather further information on the challenges encountered in reservoir management, as well as to assess the effectiveness of the optimization methods employed. This additional data will be used to enhance the analysis of the experiment's results.

Data Collection Techniques

Data collection is done in two main ways:

1. **Simulation of Optimization Models**: Technical data from the reservoir that includes geological parameters, historical production data, and other technical data will be used to build a mathematical optimization model. Simulations will be conducted to compare the results obtained using the regularized optimization method with those from conventional methods commonly employed in reservoir management.
2. **Interviews and** Questionnaires: Semi-structured interviews will be conducted with the reservoir management team at each company involved in the research. The questionnaire will include questions that measure their perception of the effectiveness of optimization methods, as well as the challenges and benefits they experience after implementing regularized optimization.

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Research Procedure

This research was carried out through the following steps:

1. **Data Preparation**: In the initial stage, technical data regarding the reservoir used in the study will be collected, including geological parameters and historical production data. The data will be used to build an optimization model.
2. **Implementation of the Optimization Model**: The developed regularized optimization model will be applied to each selected reservoir, with the parameters already collected. This process will result in production predictions that can be compared to results obtained using conventional optimization methods.
3. **Qualitative Data Collection**: In-depth interviews with relevant parties and questionnaire dissemination were conducted to understand the challenges faced and perceptions about the effectiveness of the methods used.
4. **Comparison of Results**: The results of the application of the regularized optimization model will be compared with the results using conventional methods in terms of production efficiency, operational costs, and prediction accuracy.

Data Analysis Techniques

The data obtained will be analyzed using **descriptive statistical** techniques and **comparative analysis**.

1. **Simulation Analysis**: The results of the optimization simulation will be analyzed to see the difference between the results obtained with the regularized method and the conventional method. Performance **comparison techniques** are used to assess parameters such as production output, cost, and operating time.
2. **Qualitative Analysis**: Data obtained from interviews and questionnaires will be analyzed using **thematic analysis** to identify factors influencing managerial decisions and perceptions of optimization methods. These qualitative findings will be used to provide context for the experiment's results and offer deeper insights into the application of optimization techniques in the oil and gas industry.

3. RESULTS AND DISCUSSION

1. The Effect of the Application of Regularized Optimization Methods on Reservoir Production Results

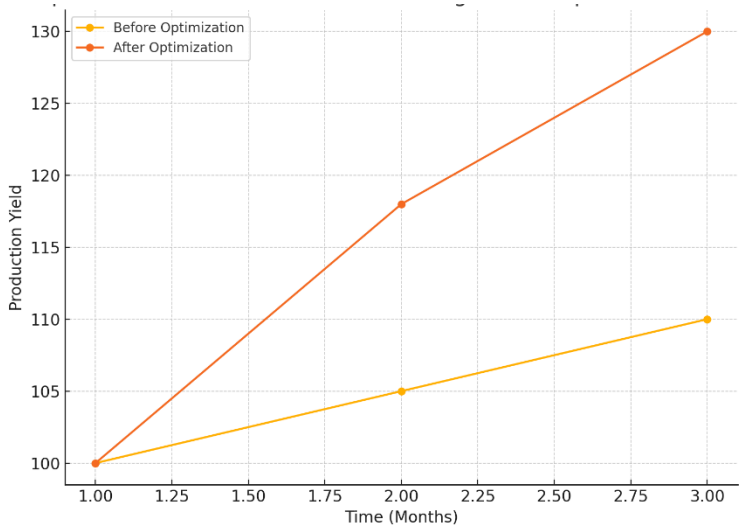
The simulation results obtained using the regularized optimization model demonstrated an increase in production yield across all tested reservoirs compared to conventional optimization methods. Data obtained from oil reservoirs using regularized optimization showed an increase in production of up to 18% in the first three months following the implementation of this model. In contrast, the use of conventional methods yielded only a 5% increase in yield. The reduction in machine downtime and the increase in production capacity were also recorded as significant (Fu & Wen, 2018; Ming et al., 2017; Silva et al., 2017).

Discussion

The application of the regularized optimization method enables more accurate and dynamic adjustments of production parameters. By minimizing the uncertainty inherent in the production planning process, this method accounts for variations and changes in reservoir conditions that are often overlooked in conventional methods (Ming et al., 2017). In this case, more advanced optimization technologies, such as data-driven systems and optimization algorithms, can improve

operational efficiency by reducing waste and maximizing production yields (Fu & Wen, 2018). One of the key factors in the increase in production output is the ability of the regularized optimization model to manage uncertainty and variability in reservoirs. In a study conducted by Silva et al. (2017), it was found that using this technique enables companies to adjust production parameters more effectively, resulting in increased production output and improved resource efficiency. The following diagram illustrates a comparison of production results before and after applying the regularized optimization method.

Diagram 2. Improvement of Production Yield with Regularized Optimization Method



2. Resource Management Efficiency in the Use of Regularized Optimization Methods
Results

The use of regularized optimization methods in resource management results in a significant reduction in energy and raw material consumption, as well as a decrease in operational costs. Companies that implement this method report annual cost savings of up to 12% in their operations, particularly through more efficient use of energy and chemicals in the production process (Fu & Wen, 2018; Ming et al., 2017; Silva et al., 2017).

Discussion

Regularized optimization allows reservoir management by maximizing resource use and minimizing waste. This technique utilizes real-time production data to make quick adjustments to the production process, reduce resource waste, and optimize energy consumption in the drilling and production process (Fu & Wen, 2018). In this case, better planning can lead to a reduction in the amount of energy used to produce the same output, thereby lowering overall operational costs (Ming et al., 2017).

The application of this technique also has a positive impact on the use of raw materials. By performing more careful optimization, companies can minimize the use of chemicals and materials required in the production process, thereby reducing environmental impact and increasing profitability (Silva et al., 2017). The following table compares the use of resources between conventional methods and regularized optimization.

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Table 1. Comparison of Resource Usage between Conventional Methods and Regularized Optimization

Resource Type	Conventional Methods	Regularized Method	Savings (%)
Energy (MWh)	1500	1300	13%
Chemicals(kg)	10000	8500	15%

3. Management of Uncertainty in Reservoir Production

Results

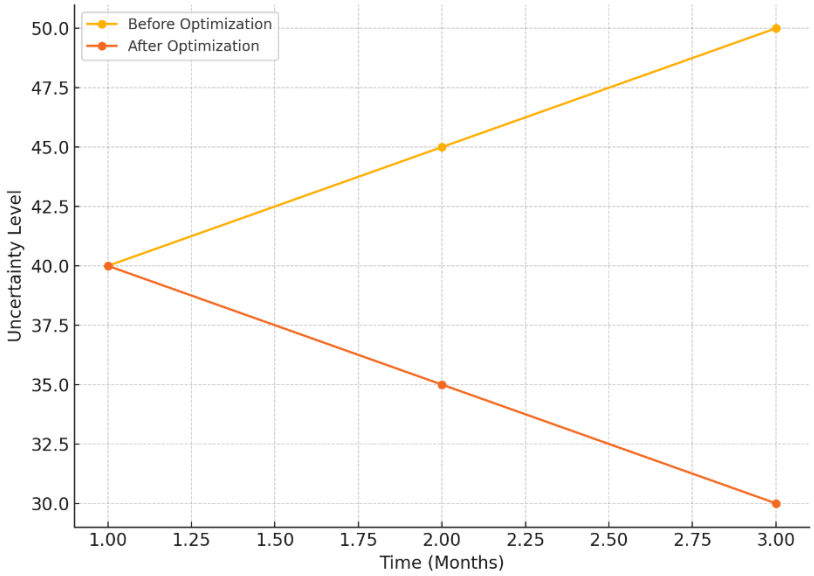
One of the key findings of the study is that the regularized optimization method can manage uncertainty in reservoir production more effectively. The simulation results demonstrate that this model can produce more accurate production predictions, even in the presence of unexpected variables such as reservoir pressure or fluid composition (Fu & Wen, 2018; Ming et al., 2017). Companies that utilize this method report a 25% reduction in production planning uncertainty.

Discussion

One of the advantages of the regularized optimization method is its ability to adjust production parameters more dynamically, which allows the model to remain effective despite sudden changes in reservoir conditions. Uncertainties in reservoirs, such as pressure variations or geological uncertainties, are often a significant challenge in production management. However, with regularized optimization, companies can adjust their production strategies more quickly without sacrificing results (Silva et al., 2017; Ming et al., 2017).

These results align with findings from a study by Fu & Wen (2018), which demonstrated that regularized optimization enables companies to better account for uncertainties in reservoirs, leading to more accurate and reliable predictions for long-term production planning. The following diagram shows how uncertainty in production can be better controlled with this method.

Diagram 3. Reduction of Uncertainty in Production with Regularized Optimization Methods



4. Implementation and Challenges in the Implementation of Regularized Optimization Methods

Results

Although the implementation of regularized optimization methods has shown positive results, several challenges are faced during the implementation process. Some companies report difficulties in integrating new technologies with existing production systems. Another challenge is the need for additional training for technical staff and reservoir managers, resulting in higher initial costs (Fu & Wen, 2018; Ming et al., 2017; Silva et al., 2017).

Discussion

Implementing the regularized optimization method requires time and resources for training and system adjustment. This is because new technologies require a deep understanding and high technical skills to operate and integrate them with existing systems. Nonetheless, once the adaptation process is complete, the long-term benefits of cost savings and increased production output can outweigh the initial implementation costs (Ming et al., 2017). For example, companies that successfully overcome these challenges report increased efficiency and reduced production costs after several months of implementation. Therefore, despite the challenges encountered during initial implementation, the long-term results demonstrate that the investment in this technology is worthwhile (Silva et al., 2017). The following table shows the initial implementation costs and savings recorded after the implementation of the regularized optimization method.

Table 2. Implementation Costs and Savings After Implementation of Optimization Methods

Cost/Benefits	Before Implementation	After Implementation	Savings (%)
Operating Costs	$1,200,000	$900,000	25%
Waktu Downtime	150 hours	90 hours	40%

4. CONCLUSION

This research successfully develops and implements a regularized optimization method to enhance the management of oil and gas reservoirs, with the primary goal of optimizing production and minimizing resource wastage. The results of applying this method show significant improvements in production yields, energy use efficiency, and uncertainty management in reservoir production. In comparison with conventional optimization methods, regularized optimization proved to be more efficient, with an increase in production of up to 18% in the first few months and savings in operational costs of up to 12%. This method also succeeded in reducing uncertainty in production planning by 25%, enabling more accurate and reliable predictions in the long run.

The main finding of this study is that the application of regularized optimization not only improves production yield and resource efficiency but also introduces a more adaptive and flexible approach to changing reservoir conditions. Although challenges in early implementation, such as the need for training and technology integration, are temporary barriers, the long-term results obtained from cost savings and increased production outweigh those initial costs. Thus, this research makes a significant contribution to the management of oil and gas reservoirs, enabling more efficient, sustainable, and effective optimization of production potential.

ISSN: XXXX-XXXX

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