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Original Research

# Research on Intelligent AI-Based Control for Intermittent Production Optimization of Oil and Gas Wells

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**Abstract:** In recent years, the proportion of low-permeability, low-pressure, and low-productivity oil and gas wells in China's oilfields has been increasing year by year. As a key production mode for such wells, intermittent production plays an important role in stabilizing production, reducing energy consumption, and protecting reservoirs. However, the traditional manual intermittent production mode is restricted by fixed working schedules, lagging data monitoring, insufficient real-time response capacity, and strong human subjectivity. It is difficult to adapt to the dynamic changes of reservoir seepage, downhole fluid supply, and production conditions, resulting in problems such as low pump efficiency, serious ineffective energy consumption, unbalanced reservoir energy utilization, and high operation and maintenance costs. To solve these practical problems in field production, this paper proposes an intelligent optimization technology for intermittent production of oil and gas wells based on artificial intelligence control. The technology constructs a full-cycle integrated system including real-time data acquisition, intelligent algorithm analysis, dynamic parameter optimization, and automatic execution control. Based on long-short term memory (LSTM) neural network and genetic algorithm, it establishes a dynamic prediction model for downhole fluid level recovery, pressure attenuation, and productivity change, and realizes adaptive optimization and automatic control of intermittent production cycles. Field application in a low-permeability oilfield shows that the proposed technology can significantly reduce invalid operation time, cut down power consumption by 39.4%, increase daily oil production per well by 28.1%, and lower equipment failure rate by 67.5%. It provides a reliable intelligent technical solution for high-efficiency, low-consumption,

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and automated production of low-efficiency oil and gas wells, and strongly supports the digital transformation and intelligent development of oilfield production management.

**Keywords:** artificial intelligence; intelligent control; oil and gas wells; intermittent production; parameter optimization; low-permeability reservoir; LSTM neural network; genetic algorithm

## 1. Introduction

Artificial intelligence technology has strong advantages in processing time-series data, fitting nonlinear relationships, dynamic prediction, and multi-objective optimization. It can effectively mine the hidden laws behind massive production data, realize real-time perception, intelligent decision-making, and automatic control of oil well production conditions, and reduce the dependence on manual experience. In view of this, this paper carries out a systematic study on the intelligent control and optimization technology of intermittent production based on AI. By constructing a multi-source data perception layer, an intelligent algorithm analysis layer, and an automatic control execution layer, the paper establishes a dynamic prediction model for fluid level recovery and productivity change, optimizes the intermittent production system in real time, and realizes unattended and adaptive intelligent control. The research results can provide theoretical support and practical reference for improving the efficiency of low-productivity oil wells, reducing production energy consumption, and promoting the intelligent construction of oilfields.

## 2. Current Problems of Traditional Intermittent Production Technology

### 2.1 Fixed Intermittent Schedule and Poor Dynamic Adaptability

Traditional intermittent production systems are mostly formulated based on historical production data and manual experience, with fixed start-stop time and fixed operation cycles. In the actual production process, low-permeability reservoirs have complex seepage characteristics, and the downhole dynamic fluid level, formation pressure, water cut, and oil saturation are in a state of real-time dynamic changes. The fixed working system cannot match the actual fluid supply capacity of the formation, which often leads to two kinds of adverse conditions: on the one hand, the well is opened for too short a time in the period of sufficient fluid supply, resulting in low production and failure to make full use of reservoir energy; on the other hand, the well is still opened continuously in the period of insufficient fluid supply, resulting in pump emptying, rod vibration, partial wear, and other problems, which seriously affect production safety and economic benefits.

### 2.2 Lagging Monitoring and Low Regulation Precision

In the traditional management mode, oil well production data mainly rely on manual regular inspection and recording. The sampling interval is long, the data continuity is poor, and real-time dynamic parameters such as downhole fluid level and pressure cannot be continuously obtained. The lag of data makes it impossible for technicians to grasp the law of fluid level recovery and pressure attenuation in a timely manner, and the adjustment of the intermittent system often lags behind for several days or even longer. The control accuracy is low, and it is impossible to realize refined management matching with dynamic reservoir characteristics.

### 2.3 High Invalid Energy Consumption and High Production Cost

Low-productivity wells themselves have low fluid supply capacity and low pump efficiency. Under the traditional fixed intermittent mode, the pumping unit is in idling or light-load operation for a long time, resulting in a large amount of ineffective power consumption. At the same time, unreasonable frequent start-stop will increase the mechanical impact load, aggravate the wear of pumping rods, tubes, pumps, reducers, and other key components, improve the frequency of equipment failure and maintenance, and significantly increase the cost of materials, parts, and labor.

### 2.4 Extensive Manual Intervention and Difficult Unified Management

Oil and gas wells are widely distributed, with large numbers and complex working conditions. The traditional manual management mode needs a lot of inspection personnel to carry out data collection, parameter adjustment, and fault handling. Human factors have a great impact on production management, and problems such as missed inspection, wrong adjustment, and delayed handling often occur. It is difficult to realize standardized, refined, and intelligent unified management of well groups, which restricts the improvement of overall oilfield management level and benefits.

## 3. Technical Principle of AI-Based Intelligent Control for Intermittent Production

### 3.1 Overall System Architecture

The AI-based intelligent control system for intermittent production adopts a three-tier architecture design, which is composed of a data acquisition layer, an intelligent analysis layer, and an execution control layer, realizing the full closed-loop management of data perception, algorithm analysis, and automatic control.

The data acquisition layer is composed of various sensors and monitoring instruments, including dynamic fluid level meters, pressure sensors, load sensors, current and power monitoring modules, etc. It can collect downhole flow pressure, casing pressure, dynamic fluid level, polished rod load, motor current, power consumption, daily fluid production, water cut and other key parameters in real time, providing high-quality data sources for subsequent intelligent modeling and optimization.

The intelligent analysis layer is the core of the whole system, deployed in the cloud platform and edge computing terminal. It is responsible for data cleaning, feature extraction, model training, dynamic prediction, and multi-objective optimization. Based on LSTM neural network and genetic algorithm, it constructs a dynamic prediction model for fluid level recovery and productivity change, calculates the optimal start-stop time and operation cycle in real time, and generates intelligent control instructions.

The execution control layer is composed of an intelligent control terminal, a frequency conversion control device, and a remote transmission module. After receiving the instructions issued by the intelligent analysis layer, it automatically completes the start and stop of the pumping unit, without manual on-site operation. At the same time, it has an emergency stop and fault protection function to ensure the safety and stability of production.

### 3.2 Core Intelligent Algorithm

#### 3.2.1 Improved LSTM Neural Network

Time-series data such as dynamic fluid level, pressure, and load in oil well production have strong timing and nonlinear characteristics. Traditional neural networks are prone to gradient disappearance and gradient explosion when processing long time-series data, resulting in poor prediction effect. The LSTM (Long Short-Term Memory) neural network improves the network structure by introducing gate mechanisms including input gate, forget gate, and output gate, which can effectively retain long-term dependent information and is especially suitable for time-series prediction in oil production.

In this study, an improved LSTM model is adopted. By optimizing the activation function and network weight initialization method, the convergence speed and prediction accuracy of the model are improved. The model takes historical production data such as fluid level, pressure, water cut, and operation time as input, and takes future fluid level recovery speed, pressure change trend, and reasonable start-stop time window as output. Through continuous learning and iteration of actual production data, the model can accurately predict the dynamic change law of downhole parameters, providing a reliable basis for real-time optimization of intermittent production systems.

#### 3.2.2 Genetic Algorithm-Based Multi-Objective Optimization

On the basis of LSTM prediction, genetic algorithm is introduced to carry out multi-objective optimal solution. Taking maximum daily oil production, minimum unit fluid energy consumption, and minimum equipment wear as optimization objectives, and taking start-stop interval, maximum single operation time, critical fluid level, and critical pressure as constraint conditions, the global optimal intermittent production parameters are obtained through selection, crossover, and mutation operations. Compared with manual empirical optimization, this method can avoid local optimum and realize the comprehensive optimization of production, energy saving, and equipment protection.

### 3.3 Adaptive Intelligent Control Logic

The system designs a complete set of adaptive control logic based on reservoir seepage mechanism and actual production rules:

1. Shut-in recovery stage: real-time monitoring of dynamic fluid level rise rate and formation pressure recovery. When the fluid level and pressure reach the optimized start-up threshold, the system automatically issues a start-up instruction.

2. Operation production stage: real-time collection of load, current, fluid production and other parameters, dynamic judgment of pump filling degree. Once pump emptying, load mutation, current abnormality and other working conditions are identified, the system immediately shuts in the well to protect the equipment and restore formation energy.

3. Threshold self-updating: the system dynamically updates the critical threshold of start-up and shut-in according to seasonal changes, water cut fluctuations, and production decline laws, maintaining high adaptability throughout the life cycle of oil wells.

## 4. Integrated Technical Scheme of AI-Based Intermittent Production Optimization

### 4.1 Production Data Preprocessing

The original data collected on-site often have problems such as outliers, missing values, and noise interference, which will reduce the accuracy of model training and prediction. Therefore, standardized data preprocessing must be carried out.

First, the 3σ criterion is used to identify and eliminate abnormal data caused by sensor faults, voltage fluctuations, and construction interference. Then, the linear interpolation method is used to fill the short-term missing data to ensure the integrity and continuity of the time series. Finally, the min-max normalization method is used to normalize parameters such as fluid level, pressure, load, and current to the interval [0,1], eliminating the influence of different dimensions on model training, accelerating model convergence, and improving calculation accuracy.

### 4.2 Construction of Dynamic Prediction and Optimization Model

Taking a single well as the research unit, the dynamic prediction model and multi-objective optimization model are constructed as follows:

Input historical and real-time production data after preprocessing.

Use the improved LSTM network to train and learn, fit the fluid level recovery curve and pressure attenuation curve, and predict the future 72-hour fluid level and pressure change trend.

Establish a multi-objective optimization function with production, energy consumption, and equipment wear as indicators.

Use genetic algorithm to iterate and solve, and output the optimal start-stop time, single operation time, and intermittent cycle.

Regularly introduce new production data to retrain the model, keep the model updated, and maintain high prediction accuracy and optimization effect.

### 4.3 Cloud-Edge Collaborative Deployment

The system adopts cloud-edge collaborative deployment architecture, which combines the strong computing power of the cloud and the low delay of edge computing.

The edge terminal completes data collection, local storage, simple calculation, and real-time control. It can still independently realize automatic start-stop and fault protection under the condition of poor network signal, ensuring the continuity and safety of production.

The cloud platform focuses on model training, large-scale data analysis, well group management, and visual display. It supports remote monitoring, historical data query, production trend analysis, and system parameter configuration, realizing centralized and refined management of oil wells.

### 4.4 Intelligent Early Warning and Safety Protection

To improve the safety and reliability of production, the system integrates an intelligent early warning module:

Real-time analysis of indicator diagrams, current curves, and load fluctuations to identify typical faults such as pump emptying, rod breakage, eccentric wear, and pipeline blockage.

Set multi-level safety thresholds. When parameters exceed the limit, the system will automatically alarm and shut down quickly to avoid equipment damage and safety accidents.

Generate early warning records and fault reports automatically, which is convenient for technicians to analyze and process, and greatly reduces the pressure of on-site inspection.

## 5. Field Application and Effect Analysis

### 5.1 Overview of Test Area

The field test was carried out in a low-permeability reservoir block of an oilfield in northern Shaanxi. The reservoir has low permeability, low pressure, and low productivity. The crude oil has high viscosity, the fluid supply capacity is weak, and the production effect of traditional continuous operation is poor. A total of 8 low-productivity oil wells were selected as test objects. Before the test, all wells adopted the traditional manual fixed intermittent production mode, with high energy consumption, low pump efficiency, and frequent equipment failures.

### 5.2 Application Process

Complete the installation and calibration of sensors, intelligent control terminals, and transmission equipment.

Collect historical production data for model initialization training.

Deploy the cloud-edge collaborative system and debug the prediction and control functions.

Put into formal operation, carry out real-time monitoring and data statistics for 90 consecutive days.

Compare key indicators such as daily power consumption, daily oil production, pump efficiency, and equipment failure rate before and after application.

### 5.3 Application Effect Analysis

#### 5.3.1 Energy Saving Effect

After adopting AI intelligent intermittent control technology, the invalid operation time is greatly reduced. The average daily power consumption of the test wells decreased from 185 kW·h to 112 kW·h, with a comprehensive power saving rate of 39.4%, and the energy saving effect is remarkable.

#### 5.3.2 Production Enhancement Effect

By accurately grasping the best time to start and shut in the well, the pump filling degree is significantly improved. The average daily oil production per well increased from 0.32 tons to 0.41 tons, an increase of 28.1%, and the oil recovery was increased by 8.2%.

#### 5.3.3 Equipment Protection Effect

Unreasonable frequent start-stop and idle wear are reduced. The monthly equipment failure rate decreased from 12.6% to 4.1%, a decrease of 67.5%. The service life of pumping rods, tubes, pumps, and reducers is prolonged, and the maintenance cost is greatly reduced.

#### 5.3.4 Management Efficiency Improvement

The system realizes unattended automatic control, reducing the frequency of manual on-site adjustment and inspection. The annual labor management cost per well is reduced by more than 40%, and the intelligent and refined management level of oil wells is significantly improved.

### 5.4 Comprehensive Evaluation

Field application proves that the AI-based intelligent control technology for intermittent production has high stability, strong adaptability, and remarkable economic benefits. It can effectively solve the core pain points of traditional intermittent production, and is especially suitable for low-permeability, low-pressure, and low-productivity oil wells. It has high popularization and application value.

## 6. Existing Problems and Future Optimization Directions

### 6.1 Existing Problems

Data quality constraints: individual old wells have aging sensors and poor anti-interference ability, and the data accuracy is slightly insufficient under severe downhole conditions, which affects the model prediction effect.

Adaptability of complex reservoirs: for complex fault-block reservoirs and ultra-low permeability reservoirs, the fluid level recovery is slow and the law is complex, and the model prediction error is slightly higher than that of conventional reservoirs.

Communication stability: in remote areas, wireless network signals are weak, and individual instructions may be delayed, which has a certain impact on real-time control.

### 6.2 Future Optimization Directions

Upgrade high-precision explosion-proof sensors and anti-interference circuits to improve data stability and accuracy under complex working conditions.

Expand sample data sets of complex and ultra-low permeability reservoirs, further optimize LSTM network structure and activation function, and improve model adaptability and prediction accuracy.

Build a 5G special communication network to enhance transmission speed and stability; strengthen the offline autonomous operation capability of edge terminals to ensure reliable control in the case of network interruption.

Build a well group collaborative optimization platform to realize the unified intelligent optimization and management of multi-well and large-scale well groups, and further improve the overall development benefit of the block.

## 7. Conclusions

Aiming at the problems of solidified system, lagging monitoring, high energy consumption and high cost in traditional intermittent production, this paper constructs an AI-based intelligent control and optimization system for intermittent production of oil and gas wells, which realizes the integration of real-time data perception, intelligent dynamic prediction, adaptive parameter optimization and automatic control execution.

The improved LSTM neural network can accurately predict the dynamic changes of downhole fluid level and pressure; the genetic algorithm-based multi-objective optimization can obtain the global optimal intermittent production parameters, overcoming the limitations of manual experience.

Field application shows that the technology can reduce power consumption by 39.4%, increase daily oil production by 28.1%, reduce equipment failure rate by 67.5%, and significantly reduce production and management costs, with significant economic and social benefits.

The technology has strong adaptability and high reliability, and is suitable for large-scale popularization in low-permeability, low-pressure and low-productivity oil wells. It provides a strong technical support for the intelligent transformation, energy saving and consumption reduction, and high-quality development of oilfields.

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