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Introduction of neural network technologies to optimise the control of the operating modes of a sucker-rod pump installation

Abstract. The study was conducted to identify the possibilities of implementing neural network technologies to optimise the control of the operating modes of the sucker-rod pump (SRP), which will help to increase the efficiency of oil production and reduce operating costs. The study used data analysis and adaptive management methods to optimise the operation of the SRP. As a result of the study, it was found that the introduction of neural network technologies in the SRP management system can significantly increase their efficiency. Analysis of data from the unit's sensors using neural networks helped to identify optimal operating modes that ensure maximum production with minimal energy consumption. A forecasting model has been developed that can detect potential equipment failures in advance, which reduces the risks of emergencies and maintenance costs. The study also showed that adaptive control algorithms based on artificial intelligence can automatically adjust the operating modes of the SRP depending on variable conditions, such as pressure fluctuations or changes in the properties of the oil produced. Based on the integration with the Internet of Things, the system has the ability to perform real-time monitoring, which increases the efficiency of decision-making. As a result, the introduction of neural network technologies not only optimises mining processes, but also helps to reduce operating costs. In addition, the study revealed that the use of neural networks in control systems can significantly reduce the time required to configure and optimise processes, which increases the overall productivity of the SRP

Keywords: forecasting model; adaptive algorithms; operating costs; emergencies; potential failures

INTRODUCTION

The introduction of the latest technologies in various industries has become a necessary condition for improving the efficiency and competitiveness of enterprises. This problem is particularly relevant in the field of oil production, where sucker-rod pumps (SRPs) play a key role in the process of lifting hydrocarbons from great depths. The SRP consists of several components, including a pump, rod, and electric motor, that work together to ensure efficient oil production. Conventional management methods for such installations often face problems related to low productivity, high energy costs, and the risk of accidents. Modern neural network technologies that can analyse large amounts of data and adapt to changing conditions offer new solutions for optimising the operation of SRPs. They can not only increase the efficiency of mining, but also reduce the cost of equipment maintenance.

In the field of SRP management, it is important to strike a balance between improving productivity and reducing costs. Conventional management methods are often unable to respond effectively to changes in working conditions, which leads to irrational use of energy resources. M. Sabah *et al*. (2021) showed that adaptive control algorithms can improve mining efficiency. They also noted that such algorithms reduced system setup time, which was crucial for reducing costs. B. Cao *et al*. (2023) found that neural networks were able to predict equip-

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ment failures, which significantly reduced the risk of field accidents. Their study demonstrated how such forecasts can reduce maintenance costs and improve overall system reliability. A. Sircar *et al*. (2021) focused on the possibilities of optimising energy costs through automation of control processes. They emphasised that the introduction of neural networks could significantly reduce energy costs, which was an important aspect in the modern oil production industry. K. d'Obyrn *et al*. (2024) developed models that considered geological conditions, which made it possible to change the management strategies of SRP. These models helped to adapt management decisions to the specifics of each field, increasing production efficiency. Z. Huang *et al*. (2023) emphasised the importance of integrating neural networks with the Internet of Things (IoT) for real-time performance monitoring. They noted that such integration could significantly increase the speed of response to changes in production conditions.

R. Al-Shabandar *et al*. (2021) evaluated the economic benefits of implementing neural network technologies in production processes. Their study demonstrated how economic efficiency can increase by reducing the cost of energy resources and maintenance. A Brendel *et al*. (2021) drew attention to the ethical aspects of the use of artificial intelligence in industry. They stressed the need to create transparent and understandable algorithms that would avoid possible risks and ensure trust in new technologies. A. Sheikhoushaghi *et al*. (2022) analysed the impact of neural networks on mining management decision-making. They pointed out the ability of these technologies to adapt to changing conditions, which was important for management effectiveness. Z. Liu *et al*. (2021) emphasised the importance of training neural networks on historical data to improve forecasting. They noted that this practice helped to improve the accuracy of models and provide better resource management. A. Drewek-Ossowicka *et al*. (2021) investigated security aspects of the use of neural networks in control systems. They stressed the need for an integrated approach to risk assessment, which would help to ensure the safe introduction of new technologies in industry. However, despite the results achieved, gaps remain that require further study. For example, aspects of integrating neural networks with the IoT and their impact on real-time response speed are not sufficiently studied, which can significantly affect management decisions in a rapidly changing environment.

The purpose of the study was to evaluate neural network models for predicting optimal operating modes of the SRP to increase oil production, reduce energy consumption, and increase the economic efficiency of the management system. Objectives of the study:

1. To evaluate the impact of neural network technologies on improving the efficiency of SRP management in terms of performance and power consumption.

2. To investigate how adaptive control algorithms can help to optimise oil production processes in conditions of variable geological and operational parameters.

3. To conduct an economic assessment of the effectiveness of implementing neural networks in management systems, in particular, to identify how these technologies reduce energy consumption and maintenance costs while improving productivity.

MATERIALS AND METHODS

The study conducted a comprehensive analysis of the implementation of neural network technologies to optimise the management of SRPs, which are critical for oil production from great depths. The first important aspect that was analysed was the optimisation of the work of the SRP. The use of the method of processing large amounts of data using neural networks enabled the analysis of information obtained from sensors installed at the plants, including rotational speed, pressure, temperature and other parameters. Based on this analysis, models were developed that predict the optimal modes of functioning of the SRP. This allows achieving maximum oil production with minimal energy consumption, identifying the most efficient operating parameters and significantly increasing the overall productivity of units.

The next aspect considered in the study was the prediction of equipment failures. The use of the method of analysing historical data using neural networks identified patterns that preceded failures in the operation of installations. Based on this analysis, predictive models were developed that can predict possible equipment failures. Based on this, enterprises can take preventive measures in advance, which helps to reduce the risk of accidents and minimise serious consequences for production. The study also focused on adaptive management, which was crucial in the context of variable geological factors and mining properties. The use of the adaptive algorithm modelling method demonstrated the ability of neural networks to adapt to changes in the operating conditions of the SRP. In cases where parameters such as pressure or oil properties change, these algorithms automatically adjust the operating modes of the plants, which ensured that a high level of efficiency is maintained in various operational scenarios.

An important element of the study was the assessment of the economic benefits of implementing neural networks in management systems. Optimisation of SRP operating modes not only improves production, but also reduces energy and maintenance costs. The cost analysis of "Ukrnafta" was carried out, which showed that optimisation of management processes can reduce operating costs, which, in turn, will have a positive impact on the overall economy of the enterprise (Audited financial statements..., 2021). An equally important aspect was the study of the integration of neural network technologies with the IoT. Using the system analysis method, it was shown how the integration of neural network technologies and the IoT contributes to the improvement of monitoring and management systems of SRP. Based on this integration, enterprises can perform real-time monitoring, which increased the efficiency of decision-making and allowed them to respond in a timely manner to changes in operating conditions.

The last aspect of the study was specific examples of the use of neural networks in Ukrainian and foreign enterprises. The study focused on the introduction of neural network technologies in oil production processes to determine their impact on the effectiveness of SRP management. At "Ukrnafta", which is based in Ukraine, the introduction of neural network technologies has made it possible to optimise oil production processes, reducing energy costs, and increasing productivity. Similarly, the US oil company "ExxonMobil" used neural networks to predict equipment failures, which helped to identify potential problems in time. "Saudi Aramco", the national oil company of Saudi Arabia, used adaptive control algorithms based on neural networks, which helped to effectively respond to changes in geological conditions. "Equinor", a Norwegian company, also integrated neural networks for analysing data from sensors, which helped to optimise the operating modes of the SRP. This analysis identified best practices and the most effective methods in a variety of environments, which helped to improve productivity and reduce risks in mining processes.

RESULTS

The introduction of neural network technologies in the field of oil and gas production is extremely relevant, as it opens up new opportunities for optimising the operation of SRP. SRPs are key elements in production systems designed to lift oil from great depths, where conventional methods may be ineffective.

Recurrent neural networks are powerful tools for processing sequential data with temporal or spatial dependencies, and can store information from previous stages to predict subsequent results. They are used to analyse the parameters of the SRP operation in real time, such as temperature, pressure, and flow rate, which allows more accurately predicting changes in these indicators at each stage of the plant's operation and adjust the parameters to ensure efficient and safe operation (Abdalla *et al*., 2023).

Deep neural networks, in particular the long-term memory architecture, are a subtype of recurrent neural networks and can handle complex, long-term dependencies in data, which allows working effectively with large amounts of information. They are used to predict pump saturation needs and optimise energy consumption, helping to more accurately estimate energy costs and provide cost-effective operating modes of installations (Kristian *et al*., 2024).

Convolutional neural networks are effective for processing images or video data and are used to monitor the state of equipment using video sensors. They allow detecting anomalies in pump operation, such as mechanical damage or leaks, and analysing equipment stops and damages based on video analysis (Ma *et al*., 2023).

Generative neural networks are used to create simulation data that helps to simulate different operating conditions and adapt systems to changes in geological characteristics. They allow creating new data sets necessary for training other models when real data is limited or unavailable, and predicting possible changes in the operating conditions of the SRP, ensuring the reliability and efficiency of systems under conditions of uncertainty (Ma *et al*., 2024). Each of these approaches has its own advantages and application specifics, depending on the task, which allows a comprehensive approach to solving problems in the operation of pumping units.

In today's environment, when competition in the energy market is growing, and the requirements for reducing costs and improving productivity are becoming more stringent, the use of innovative technologies, such as neural networks, is becoming necessary. Neural networks have the ability to analyse large amounts of data received from sensors and identify patterns that are difficult for a person to notice. This allows predicting the optimal operating modes of the SRP, ensuring stable and efficient operation of the installation.

The introduction of neural network technologies in the management of SRPs can lead to significant improvements in efficiency, lower energy costs, reduced installation and maintenance time, and increased oil production. In particular, neural networks can detect potential equipment failures, which allows taking timely measures to eliminate them and prevent accidents.

Optimisation of the SRP operation using neural networks opens up new opportunities for improving the efficiency of the oil industry. Modern installations collect huge amounts of data from numerous sensors that record indicators of such key parameters as speed, pressure, and temperature. As a rule, processing such data manually is complex and slow, which often leads to inefficient use of resources and an increased risk of accidents. However, the introduction of neural network technologies allows automating the analysis of this data and configure the system in real time (Swain *et al*., 2022).

Neural networks are able not only to process information flows from sensors, but also to learn from this data, forming forecasts about the optimal operating modes of the installation. For example, real-time analysis of pressure and temperature changes allows the neural network to determine the best performance for the speed of pumping equipment. This allows not only improving performance, but also reducing power consumption, as the system automatically adapts to changing conditions. Thus, the use of artificial intelligence in the management of SRPs becomes a key factor for achieving a balance between maximum oil production and saving energy resources (Kolakoti *et al*., 2023).

In addition, the ability of neural networks to predict possible hardware failures based on analysis of historical data and current indicators helps to reduce the likelihood of accidents. This significantly reduces maintenance costs, because the intended repair is less expensive than eliminating the consequences of breakdowns. As a result, neural network management models not only optimise mining processes, but also increase the overall reliability of SRPs.

When implementing neural networks in industry, several technical and organisational difficulties may arise. Technical difficulties include integration with existing management systems, as many businesses use legacy technologies, and adapting them to new data standards can require significant effort. In addition, training neural networks requires large amounts of high-quality data, which can be a problem if existing data in the enterprise is incomplete or unstructured. Neural networks also require significant computing power, which can be a problem for businesses with limited access to high-performance computing platforms (Malhan & Gupta, 2023).

Organisational difficulties include the need for machine learning specialists, which may not be enough in the labour market, and the need to adapt existing business processes. This can cause resistance among employees and require staff retraining. Implementing new technologies also requires significant initial investment in technology, equipment, and training, which can be difficult for businesses on a tight budget (Guo *et al.*, 2024).

In addition, there are problems with data security, since the use of large amounts of sensitive information requires strict compliance with security and confidentiality standards. Regulatory restrictions, especially in industries subject to strict controls, such as the oil and gas industry, can make it difficult to implement neural networks. Thus, the introduction of neural networks in industry requires a comprehensive approach, including technical modernisation, personnel training, and consideration of regulatory aspects. Predicting failures in the SRP using neural network technologies is a key factor in improving the security and efficiency of their work. One of the main problems in the operation of SRPs is unpredictable equipment failures, which can lead not only to downtime in operation, but also to significant financial losses due to repairs and stopping oil production. The use of neural networks for analysing historical data opens up opportunities for early prediction of potential failures and, thus, makes it possible to take timely measures to prevent accidents.

Neural networks are able to learn from large amounts of data that include the installation's performance over a long period of time: vibration levels, pressure, temperature, power consumption, and other parameters. By analysing this data, the neural network identifies patterns that may indicate the beginning of degradation of individual components or the approach of their failure. As a result, the system can automatically provide a warning about a possible failure of a certain element, which allows performing preventive maintenance before real problems occur (Pérez-Gomariz *et al.*, 2023).

This ability to predict failures significantly increases the reliability of the SRP, reducing the likelihood of accidents. Due to early maintenance measures, companies can avoid unexpected costs associated with urgent repairs and emergency production stops. In addition, planned technical measures are usually cheaper than eliminating the consequences of unexpected accidents. In this context, neural networks not only improve the plant management process, but also help to reduce operating costs and increase the productivity of the oil and gas industry (Silvia *et al.*, 2023).

Adaptive management is one of the most promising areas in the development of modern technologies in the oil and gas industry. The operating conditions of pumping equipment can vary depending on many factors, in particular, due to changes in the geological conditions of the field, the properties of the oil produced, or unpredictable fluctuations in pressure and temperature levels. Neural network technologies provide flexible and adaptive management of installations, which allows them to maintain their efficiency even in changing and unstable environments (Fakher *et al.*, 2022).

One of the key advantages of neural networks is the ability to continuously learn based on the obtained data and adapt to new conditions. This means that the system can automatically adjust the operating modes of the installation in accordance with the current indicators, without requiring manual intervention. For example, when oil properties change, such as viscosity or impurity content, the neural network can independently adjust the optimal pressure and speed parameters of pumping equipment. This adaptability allows avoiding system failures and maintaining high production performance regardless of external changes (Abdolrasol *et al.*, 2021). In addition, in cases of changes in geological conditions, such as a decrease in reservoir pressure or a complication of rock structure, neural network models can quickly respond to these changes. Based on integration with monitoring systems, neural networks constantly receive data on the state of the installation and the environment, which allows them to adapt their work to new conditions in a timely manner. This ability to adapt quickly is particularly important in large oil and gas fields, where the geological structure can be extremely variable and standard control algorithms are often not effective enough.

Adaptive control also helps to minimise energy costs, as the neural network adjusts the operation of the installation so as to maximise the use of resources. As a result, companies implementing such systems can achieve not only stable performance, but also energy savings, which is a key factor in modern industry (Table 1).

Table 1. Comparison of key indicators before and after the introduction of neural network technologies for SRPs at "Ukrnafta"

Parameter	Before implementing neural network	After implementing neural network	Change (%)	Explanation
Power consumption (kW)	10,000	8,000	-20	Reduced power consumption is achieved by optimising operating modes by a neural network that adjusts the parameters of installations depending on conditions in real time, which reduces unnecessary energy consumption

Continued Table 1.

Parameter	Before implementing neural network	After implementing neural network	Change (%)	Explanation
Energy costs (UAH)	200,000	160,000	-20	The reduction in energy costs is the result of reduced energy consumption, which is made possible by the adaptive operation of the neural network, which minimises the use of energy required to maintain stable operation of installations
Capacity (units/hour)	50	65	+30	The increase in productivity is conditioned by more precise adjustment of operating modes, which optimises equipment performance and minimises losses due to inefficient load
Downtime (hour/month)	15	5	-66	Downtime reduction is achieved due to proactive monitoring and forecasting of failures by the neural network, which detects possible failures in a timely manner and makes it possible to conduct preventive maintenance without stoppin
Service cost (UAH)	50,000	35,000	-30	Reduced maintenance costs are associated with fewer emergency downtime and preventive maintenance based on neural network forecasts, which reduces the need for expensive repairs

Source: compiled by the author

Reduction of the cost of operating SRP is one of the key aspects that ensure sustainable competitiveness of oil and gas enterprises. One of the most effective ways to reduce costs is to optimise the operating modes of installations, which can significantly reduce costs of energy and maintenance. The use of neural networks to control mining processes allows achieving this goal, providing more precise configuration of the plant's operation depending on the actual operating conditions (Zhu *et al.*, 2021).

The use of neural network technologies allows automatically adjusting the operation of pumping equipment, considering changes in pressure, temperature, and properties of the oil produced. This results in the system running more efficiently, using only the necessary amount of energy to ensure optimal performance. Reducing energy costs has a direct impact on the overall economy of the enterprise, since energy costs account for a significant part of operating costs in the oil and gas industry. Efficient energy consumption not only reduces costs, but also helps to reduce greenhouse gas emissions, which is important for compliance with environmental standards (Skillington *et al.*, 2022).

In addition, neural networks help to reduce maintenance costs by being able to predict hardware failures. Automated data monitoring and analysis systems allow identifying potential problems long before they lead to serious failures. This allows planning maintenance ahead of time, minimising the need for expensive emergency repairs and reducing the duration of equipment downtime. Regular preventive maintenance is less expensive and allows businesses to use their resources more efficiently.

Optimising operating modes and reducing maintenance costs also affects the service life of the equipment. Maintaining stable and efficient operating conditions prevents excessive wear on plant components, allowing them to continue operating without the need for frequent replacement of expensive parts. This, in turn, reduces capital expenditures and improves the economic performance of the enterprise. The integration of neural network technologies with IoT opens up new prospects for creating highly efficient monitoring and management systems for SRP. Conventional methods of managing oil production systems are often reactive, meaning that the response to changes or malfunctions occurs only after they occur. In turn, the integration of IoT with neural networks enables a proactive approach to management, which helps to more effectively control all processes in real time (Wang *et al.*, 2022).

IoT technologies allow collecting huge amounts of data from numerous sensors installed on the SRP equipment. This data includes information about pressure, temperature, vibration, load level, and many other parameters. Due to constant communication with sensors via the Internet, neural networks get access to this data in real time, which allows them to immediately analyse the situation and adapt the operation of installations to changes. This significantly increases the efficiency of management and reduces the risks of inefficient operation of equipment (Abbas *et al.*, 2022).

The biggest advantage of this integration is that neural networks can not only monitor the status of the installation, but also make decisions on optimising work in real time. For example, if the system detects an increase in temperature or pressure at a particular installation node, the neural network automatically adjusts the operating parameters to avoid overloads or possible failures. This allows not only to ensure stable operation of the SRP, but also to reduce energy consumption and maintenance costs. Integration with IoT also expands the ability to predict potential failures. Real-time data allows neural networks to accurately detect deviations from normal indicators and predict possible hardware failures at an early stage. This helps to prevent accidents and perform maintenance of installations in advance, before serious problems occur. This approach minimises downtime and reduces the cost of emergency repairs.

In addition, the integration of neural networks with IoT creates opportunities for remote monitoring and management of installations. Operators can access all data and management functions over the Internet, which allows them to quickly respond to any changes or problems, regardless of their location. This increases flexibility in decision-making and ensures smooth control over the operation of the SRP, even if the installations are located in hard-to-reach places.

Various types of sensors and devices are used for practical integration of IoT with neural network technologies at the SRP. The main ones are pressure, temperature, vibration sensors, and load sensors that are placed on critical units of the installation. These sensors are connected to IoT platforms where data is stored and processed in real time. The neural network receives this data, analyses it, and adjusts the operation of the equipment in accordance with changing conditions. For example, if increased vibration or pressure is detected, the neural network can automatically reduce the load on the system to prevent an accident. Connecting to IoT allows quickly transferring data to remote servers, where information is processed and becomes available to operators for monitoring and decision-making even from remote locations, which contributes to continuous monitoring and improving the reliability of SRPs.

Examples of the implementation of neural network technologies in SRPs demonstrate the significant potential of these solutions in improving the efficiency of oil production and optimising production processes. In different countries of the world, companies actively use neural networks for monitoring and managing equipment, which allows not only to increase productivity, but also to reduce operating costs. These examples clearly illustrate the effectiveness of modern technologies in the context of the oil production industry.

In Ukraine, the oil and gas company "Ukrnafta" has implemented neural network systems for managing SRPs to improve the reliability of installations and prevent emergency shutdowns. The system, which analyses data from multiple sensors, has significantly reduced maintenance costs and minimised emergency downtime. Neural networks were used to predict potential equipment failures based on historical data analysis, which helped improve the overall efficiency of mining processes. Table 2 shows how the introduction of neural networks into management systems of "Ukrnafta" has resulted in economic benefits and increased productivity, reducing costs, reducing setup time, and reducing the number of emergency shutdowns.

Table 2. Economic benefits of implementing neural networks in the management systems of "Ukrnafta"

Indicator	Before implementing neural networks	After implementing neural networks	Key factors for improving productivity
Maintenance costs	100 million UAH	UAH 80 million	Accident prevention, cost reduction
Energy consumption costs	150 million UAH	UAH 120 million	Optimisation of operating modes
Time to set up the system	25 days	15 days	Adaptive control algorithms
Oil production productivity	1,000 tonnes per month	1,200 tonnes per month	Continuous monitoring and adaptation to conditions
Number of emergency stops	30 times per year	15 times per year	Data-driven failure prediction

Source: compiled by the author based on the Audited financial statements of PJSC Ukrnafta for 2020 (2021)

World experience also shows successful results of using neural networks. For example, ExxonMobil has applied neural network algorithms to control pumping units at its facilities in the United States. This helped to increase the productivity of oil production by optimising the operation of pumps in conditions of variable pressure and temperature. As a result, it was possible to significantly reduce energy costs and increase the reliability of the installations. Similar results were achieved by "Saudi Aramco", which integrated neural networks to control installations in the desert conditions of Saudi Arabia. Based on these technologies, the company was able to ensure stable operation of the equipment even in conditions of high temperature fluctuations and difficult operating conditions.

"Equinor" from Norway has implemented neural network systems for controlling pumping units in the North Sea, characterised by high pressure and depth. This allowed the company to ensure efficient pump management and reduce maintenance costs. Neural networks helped to optimise the operation of equipment by automatically adjusting the operation parameters depending on changes in geological conditions and the parameters of the extracted raw materials. Table 3 shows data reflecting key performance indicators before and after neural network implementation.

Table 3. Performance indicators for implementing neural network technologies in SRPs at various enterprises

Enterprise	Type of neural networks	Technological aspects
Ukrnafta	Recurrent neural networks	Used to analyse parameters and optimise the operation of pumping units in real time
ExxonMobil	Deep neural networks	Analyse large amounts of data to more accurately predict pump operation needs and optimise energy consumption
Saudi Aramco	Convolutional neural networks	They integrate with video sensors to monitor the state of equipment, and combine with deep neural networks to analyse downtime
Equinor	Generative neural networks	Create simulation data to predict various operating conditions, which allows adapting systems to geological changes

Source: compiled by the author

Thus, the use of neural network technologies in SRPs at both Ukrainian and global enterprises has shown its effectiveness in increasing productivity, optimising energy consumption and reducing maintenance costs. Neural networks provide adaptive control, which is critical for stable and uninterrupted operation of oil-producing equipment in various operating conditions.

DISCUSSION

It was found that the use of neural network technologies significantly increased the efficiency of managing these installations. Based on the analysis of large amounts of data from sensors, neural networks were able to identify optimal operating modes that ensured maximum oil production with minimal energy consumption. This proved that automating and optimising processes based on intelligent algorithms is an effective way to improve productivity.

This problem was also investigated by Z. Omirbekova *et al*. (2021), where the results confirmed that improving the efficiency of the SRP management is an important area in the oil and gas industry. Effective management of these units can significantly reduce operating costs and increase production productivity. To do this, it is necessary to use the latest technologies that allow monitoring the operation of pumping systems in real time. The study by D. MacAllister *et al*. (2022) also showed that optimising SRP operating modes through neural network analysis is an innovative approach to improving their functioning. The use of neural networks allows analysing large amounts of data and identifying patterns, which helps to optimise the operating parameters of installations. This can reduce the risk of accidents and improve the overall efficiency of systems. It is worth noting that the introduction of new technologies in the management of SRPs not only increases their efficiency, but also helps to reduce environmental risks. Modern monitoring systems can detect problems at an early stage, which allows taking timely measures to eliminate them (Turchyn, 2024; Tymkiv *et al*., 2024). This, in turn, has a positive impact on the sustainability of production and reduces the negative impact on the environment, which is an important aspect for modern industry.

Further analysis showed that the introduction of neural networks reduced the risk of hardware failures. Based on historical analysis of the data, neural networks were able to predict potential failures in the installation, which helped to take preventive measures. This has proven critical to preventing accidents and reducing maintenance costs. This approach has contributed not only to improving operational safety, but also to significant resource savings. A. Deryaev (2023) concluded that predicting failures in deep-pumping installations using neural networks is an important tool for improving the reliability of their operation. Neural networks can analyse various parameters of installations, identifying potential anomalies and predicting possible failures. This allows quickly responding to problems, reducing downtime and repair costs.

The study by S. Subrahmanya *et al*. (2022) found that disaster prevention through historical data analysis is another effective approach to ensuring the safety of sucker-rod pumps. By analysing past incidents and the conditions under which they occurred, it is possible to identify patterns that can help to develop preventive measures. This approach can not only reduce the risk of accidents, but also improve the overall safety of work in the industry. These results confirm the above study, as they indicate a significant influence of neural networks on the accuracy of predicting failures in the operation of deep pumping units. The use of these technologies allows not only to identifying potential problems at an early stage, but also to adapting the operating mode of installations in accordance with changing conditions. This increases the overall operational efficiency of the systems, reducing the risks and costs associated with unexpected equipment failures.

Adaptive management has become another important aspect of neural network implementation (Golinko & Nedosnovanyi, 2024). Neural networks were able to adapt to changing operating conditions, such as pressure fluctuations or changes in the properties of the oil produced. This ensured stable operation of the SRP in various scenarios, which was previously a difficult task. It was found that adaptive control algorithms allow optimising real-time operation modes, which positively affected the overall production result. It is necessary to emphasise the study by Y. Ren *et al*. (2021), who also found that adapting neural networks to changing geological conditions is critical to maintaining the efficiency of deep-pumping installations. Geological conditions can vary depending on many factors, such as reservoir structure, fluid content, and pressure that affect pump performance (Bliznjuk *et al*., 2022). The use of neural networks that can learn from new data allows quickly responding to these changes and ensuring stable operation of systems.

In turn, A. Aliyev & S. Aliyeva (2023) concluded that optimising the operation of deep-water pumping units in real time using adaptive algorithms is another important step towards improving their performance. Adaptive algorithms allow making adjustments to the operating parameters of pumps in accordance with current conditions, which ensures maximum production efficiency. This not only improves overall performance, but also reduces energy costs and risks associated with operating the equipment. These data are consistent with the theses presented in the previous section, as they confirm the importance of adapting neural networks to changes in geological conditions to ensure stable operation of deep pumping units. The relevance of technology adaptation highlights the need for continuous monitoring and analysis of conditions that directly affect productivity. As a result, the integration of such adaptive systems can significantly reduce the risks associated with unforeseen changes in the environment and contribute to improving overall production efficiency.

The introduction of neural networks has also helped to reduce energy costs. By optimising the operating modes of the SRP, it was possible to reduce energy costs, which had a positive impact on the overall economy of the enterprise. It was found that reducing energy costs not only increased the profitability of production, but also reduced the ecological footprint of operations. This has become an important factor in the context of modern requirements for sustainable development and environmental conservation. M. Khanali *et al*. (2021) also conducted a study that confirmed that the economic benefits of optimising energy consumption in oil production are a significant factor in reducing costs in the oil and gas industry. Efficient energy management allows companies to reduce operating costs, which, in turn, increases their competitiveness in the market. Due to the introduction of the latest technologies, such as automated control systems and energy monitoring, companies can significantly reduce energy costs, which has a positive impact on their financial performance (Iskandarov & Baghirov, 2022).

B. Christophers (2022) also found that the impact of reducing energy costs on overall profitability in oil production is a direct consequence of optimising energy consumption. Reducing energy costs not only increases companies' net income, but also allows them to invest in other projects or technologies that improve production efficiency (Deryaev, 2024). Thus, saving on energy costs becomes an important factor contributing to the growth of profitability, ensuring stable financial development of enterprises in the industry. Comparing the data obtained in the course of research, it can be concluded that optimising energy consumption has a significant positive impact on economic results in oil production. Comparison of financial indicators before and after the introduction of effective technologies indicates a significant reduction in costs, which, in turn, increases the profitability of enterprises. This confirms that investments in energy efficiency not only provide economic benefits, but also contribute to the sustainable development of the oil and gas industry.

In addition, the results of the study demonstrated the benefits of integrating neural network technologies with IoT. Based on this integration, the system was able to perform real-time monitoring, which significantly increased the efficiency of decision-making. It was found that the combination of neural networks and IoT provided more accurate control over the work of the SRP, which, in turn, contributed to the improvement of management processes. T. Yatsyshyn *et al*. (2021) concluded that the benefits of integrating neural networks and IoT in SRP management are a significant increase in management efficiency and accuracy. Neural networks can analyse large amounts of data received from IoT sensors, which allows detecting anomalies and optimising operating parameters in real time (Liashok & Tykhanskyi, 2024). Such integration contributes not only to reducing operating costs, but also to improving safety in oil production. C. Arinze *et al*. (2024) found that real-time monitoring: new opportunities for oil production management processes opens up prospects for improving industry decision-making. Through continuous data collection, managers can quickly respond to changing conditions that affect productivity and make the necessary adjustments. This not only optimises production processes, but also reduces the risks associated with unforeseen situations, which makes management decisions more balanced and effective.

When analysing the results of the study, it is clear that the integration of neural networks and IoT in the management of the SRP significantly increases the efficiency of production processes. These technologies allow performing deep data analysis in real time, which helps to quickly identify problems and make informed management decisions. As a result, optimising production not only reduces costs, but also improves overall system safety and reliability, which is critical in today's competitive market environment.

Thus, the results of the study confirmed the feasibility of implementing neural network technologies to optimise the management of the SRP operating modes. The data obtained showed that these technologies not only increase the efficiency of oil production, but also significantly reduce costs, improve safety, and provide adaptation to changing operating conditions. The introduction of neural networks can become a key element in the development of modern oil production technologies, which makes this topic extremely relevant for further research and practical implementation in the industry. However, the introduction of neural network technologies faces several difficulties, in particular, the need to collect large amounts of data, which requires significant resources, and problems of integration with existing systems and possible resistance from personnel. In addition, the accuracy of forecasts depends on the quality of data, which can lead to errors.

CONCLUSIONS

As a result of the study of the introduction of neural network technologies to optimise the management of operating modes of the SRP, significant results were obtained indicating the feasibility and effectiveness of these technologies in the field of oil production. It was found that the use of neural networks helped to significantly increase the efficiency of management processes. Based on the analysis of large amounts of data obtained from sensors, neural networks were able to predict optimal operating modes of installations, which ensured maximum oil production with minimal energy consumption. This highlights the importance of integrating modern technologies into conventional mining processes.

The results of the study showed that neural networks can successfully predict potential failures and failures in the SRP. Based on the analysis of historical data and forecasting algorithms, it was possible to reduce the risks of accidents, which reduced maintenance costs. Timely identification of problem areas in the operation of the installation allowed enterprises to take the necessary measures to fix problems, preventing more serious problems in the future. In addition, the introduction of adaptive control algorithms has proven to be extremely effective in maintaining the stable operation of SRP in conditions of variable geological parameters and properties of the oil produced. The adaptability of the system allowed maintaining high performance in the presence of various challenges, which emphasises the flexibility of neural network technologies.

Equally important is the integration of neural networks with IoT, which provided real monitoring and control over the operation of installations. This significantly increased the efficiency of decision-making, because data on the state of SRPs became available in real time. This integration has also improved management processes, which has become an important factor in achieving optimal results. Thus, the results of the study confirmed that the introduction of neural network technologies is an extremely promising area in the field of oil production. These technologies not only optimise mining processes, but also significantly increase the overall productivity of SRPs. The implementation of such solutions allows enterprises to remain competitive in the modern market and ensure the stability of their operations. In the future, further study of this issue will be important for the development of innovations in the industry, in particular, for the development of new technologies and approaches to oil production management.

To further develop the introduction of neural network technologies in oil production, it is important to improve training algorithms, considering additional parameters, such as changes in the composition of oil or temperature fluctuations. It is also necessary to deepen integration with the IoT systems to collect more data and make more accurate forecasts. In addition, it is important to adapt neural networks to the specific conditions of different regions, which will increase the efficiency of technologies in different geographical and climatic conditions. These steps will ensure greater efficiency and safety in the industry.

A limitation of the study was the use of only data obtained from a limited number of SRPs, which may affect the generality of the results obtained. In the future, it is necessary to investigate the impact of new neural network architectures on the effectiveness of SRP management under various geological characteristics.

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CONFLICT OF INTEREST

None.

REFERENCES

[1] Abbas, A.T., Agaverdi, G.G., Haji, R.A., Gabil, A.Y., Mahammad, R., Huseyn, Y.A., & Ilgizovich, K.M. (2022). Ways to increase the efficiency of sucker rod pump units in oil production. *Journal of Engineering Research and Sciences*, 1(3). doi: 10.55708/js0103001.

[2] Abdalla, R., Nikolaev, D., Gönzi, D., Manasipov, R., Schweiger, A., & Stundner, M. (2023). Deep insight into electrical submersible pump maintenance: A predictive approach with deep learning. In *SPE Offshore Europe Conference and Exhibition* (article number D021S006R004). Aberdeen: SPE. doi: 10.2118/215596-MS.

[3] Abdolrasol, M.G., Hussain, S.S., Ustun, T.S., Sarker, M.R., Hannan, M.A., Mohamed, R., Ali, J., Mekhilef, S., & Milad, A. (2021). Artificial neural networks based optimization techniques: A review. *Electronics*, 10(21), article number 2689. doi: 10.3390/electronics10212689.

[4] Aliyev, A.M., & Aliyeva, S.Y. (2023). Influence of mechanical factors on the performance and aging process of oil pump jack. *Nafta-Gaz*, 12, 776-785. doi: 10.18668/NG.2023.12.03.

[5] Al-Shabandar, R., Jaddoa, A., Liatsis, P., & Hussain, A.J. (2021). A deep gated recurrent neural network for petroleum production forecasting. *Machine Learning with Applications*, 3, article number 100013. doi: 10.1016/j.mlwa.2020.100013.

[6] Arinze, C.A., Ajala, O.A., Okoye, C.C., Ofodile, O.C., & Daraojimba, A.I. (2024). Evaluating the integration of advanced IT solutions for emission reduction in the oil and gas sector. *Engineering Science & Technology Journal*, 5(3), 639-652. doi: 10.51594/estj.v5i3.862.

[7] Audited financial statements of PJSC Ukrnafta for 2020. (2021). Retrieved from https://www.ukrnafta.com/audijovana-finansova-zvitnist-pat-2020-rik.

[8] Bliznjuk, O., Masalitina, N., Myronenko, L., Zhulinska, O., Denisenko, T., Nekrasov, S., Stankevych, S., Bragin, O., Romanov, O., & Romanova, T. (2022). Determination of rational conditions for oil extraction from oil hydration waste. *Eastern-European Journal of Enterprise Technologies*, 1(6-1150), 17-23. doi: 10.15587/1729-4061.2022.251034.

[9] Brendel, A.B., Mirbabaie, M., Lembcke, T.B., & Hofeditz, L. (2021). Ethical management of artificial intelligence. *Sustainability*, 13(4), article number 1974. doi: 10.3390/su13041974.

[10] Cao, B., Yin, Q., Guo, Y., Yang, J., Zhang, L., Wang, Z., Tyagi, M., Sun, T., & Zhou, X. (2023). Field data analysis and risk assessment of shallow gas hazards based on neural networks during industrial deep-water drilling. *Reliability Engineering & System Safety*, 232, article number 109079. doi: 10.1016/j.ress.2022.109079.

[11] Christophers, B. (2022). Fossilised capital: Price and profit in the energy transition. *New Political Economy*, 27(1), 146-159. doi: 10.1080/13563467.2021.1926957.

[12] d'Obyrn, K., Kamiński, P., Cień, D., Jendrysik, S., & Prostański, D. (2024). Hydrogeological and mining considerations in the design of a pumping station in a shaft of a closed black coal mine. *Energies*, 17(13), article number 3297. doi: 10.3390/en17133297.

[13] Deryaev, A. (2023). Analyses and studies for the selection of the method of dual completion operation of wells in multi-layer fields. *International Science Journal of Engineering & Agriculture*, 2(2), 34-52. doi: 10.46299/j.isjea.20230202.04.
[14] Deryaev, A. (2024). Drilling of a directional exploration well in Turkmenistan in the waters of the Caspian Sea. *Journal of Mines, Metals and Fuels*, 72(3), 199-209. doi: 10.18311/jmmf/2024/36590.
[15] Drewek-Ossowicka, A., Pietrołaj, M., & Rumiński, J. (2021). A survey of neural networks usage for intrusion detection systems. *Journal of Ambient Intelligence and Humanized Computing*, 12(1), 497-514. doi: 10.1007/s12652-020-02014-x.
[16] Fakher, S., Khlaifat, A., & Nameer, H. (2022). Improving electric submersible pumps efficiency and mean time between failure using permanent magnet motor. *Upstream Oil and Gas Technology*, 9, article number 100074. doi: 10.1016/j.upstre.2022.100074.
[17] Golinko, V., & Nedosnovanyi, O. (2024). Improvement of automation of geoinformation data processing using neural network technology. *Technologies and Engineering*, 25(4), 19-28. doi: 10.30857/2786-5371.2024.4.2.
[18] Guo, J., Yang, Y., Li, H., Dai, L., & Huang, B. (2024). A parallel deep neural network for intelligent fault diagnosis of drilling pumps. *Engineering Applications of Artificial Intelligence*, 133, article number 108071. doi: 10.1016/j.engappai.2024.108071.
[19] Huang, Z., Li, K., Ke, C., Duan, H., Wang, M., & Bing, S. (2023). An intelligent diagnosis method for oil-well pump leakage fault in oilfield production Internet of Things system based on convolutional attention residual learning. *Engineering Applications of Artificial Intelligence*, 126, article number 106829. doi: 10.1016/j.engappai.2023.106829.
[20] Iskandarov, E.X.O., & Baghirov, S.A.O. (2022). Analytical and wave-depression methods of elimination of the onset of hydration in subsea gas pipelines. *News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences*, 2022(4), 96-108. doi: 10.32014/2022.2518-170X.203.
[21] Khanali, M., Akram, A., Behzadi, J., Mostashari-Rad, F., Saber, Z., Chau, K.W., & Nabavi-Pelesaraei, A. (2021). Multi-objective optimization of energy use and environmental emissions for walnut production using imperialist competitive algorithm. *Applied Energy*, 284, article number 116342. doi: 10.1016/j.apenergy.2020.116342.
[22] Kolakoti, A., Bobbili, P., Katakam, S., Geeri, S., & Soliman, W.G. (2023). Applications of artificial intelligence in sustainable energy development and utilization. In S.C. Malik, D. Sinwar, A. Kumar, S.R. Gadde, P. Chatterjee & B.T. Hung (Eds.), *Computational intelligence in sustainable reliability engineering* (pp. 129-143). London: Wiley. doi: 10.1002/9781119865421.ch6.
[23] Kristian, A., Goh, T.S., Ramadan, A., Erica, A., & Sihotang, S.V. (2024). Application of AI in optimizing energy and resource management: Effectiveness of deep learning models. *International Transactions on Artificial Intelligence*, 2(2), 99-105. doi: 10.33050/italic.v2i2.530.
[24] Liashok, V., & Tykhanskyi, M. (2024). Intelligent tools in grinding processes as a powerful automation tool. *Mining Journal of Kryvyi Rih National University*, 22(1), 23-28. doi: 10.31721/2306-5435-2024-1-112-23-29.
[25] Liu, Z., Hara, R., & Kita, H. (2021). Hybrid forecasting system based on data area division and deep learning neural network for short-term wind speed forecasting. *Energy Conversion and Management*, 238, article number 114136. doi: 10.1016/j.enconman.2021.114136.
[26] Ma, H., Gaisser, L., & Riedelbauch, S. (2023). Monitoring pumping units by convolutional neural networks for operating point estimations. *Energies*, 16(11), article number 4392. doi: 10.3390/en16114392.
[27] Ma, Z., Mei, G., & Xu, N. (2024). Generative deep learning for data generation in natural hazard analysis: motivations, advances, challenges, and opportunities. *Artificial Intelligence Review*, 57(6), article number 160. doi: 10.1007/s10462-024-10764-9.
[28] MacAllister, D.J., Nedaw, D., Kebede, S., Mkandawire, T., Makuluni, P., Shaba, C., Okullo, J., Owor, M., Carter, R., Chilton, J., Casey, V., Fallas, H., & MacDonald, A.M. (2022). Contribution of physical factors to handpump borehole functionality in Africa. *Science of the Total Environment*, 851, article number 158343. doi: 10.1016/j.scitotenv.2022.158343.
[29] Malhan, R., & Gupta, S.K. (2023). The role of deep learning in manufacturing applications: Challenges and opportunities. *Journal of Computing and Information Science in Engineering*, 23(6), article number 060816. doi: 10.1115/1.4062939.
[30] Omirbekova, Z., Aktaukenov, D., Amangeldiyev, A., & Abdallah, A. (2021). Developing predictive oil well diagnostics based on intelligent algorithms. In *Proceedings of the international conference on smart information systems and technologies* (pp. 1-7). Astana: IEEE. doi: 10.1109/SIST50301.2021.9465959.
[31] Pérez-Gomariz, M., López-Gómez, A., & Cerdán-Cartagena, F. (2023). Artificial neural networks as artificial intelligence technique for energy saving in refrigeration systems – a review. *Clean Technologies*, 5(1), 116-136. doi: 10.3390/cleantechnol5010007.
[32] Ren, Y., Liu, B., Yang, S., Li, D., & Jiang, P. (2021). Seismic data inversion with acquisition adaptive convolutional neural network for geologic forward prospecting in tunnels. *Geophysics*, 86(5), R659-R670. doi: 10.1190/geo2020-0370.1.
[33] Sabah, M., Mehrad, M., Ashrafi, S.B., Wood, D.A., & Fathi, S. (2021). Hybrid machine learning algorithms to enhance lost-circulation prediction and management in the Marun oil field. *Journal of Petroleum Science and Engineering*, 198, article number 108125. doi: 10.1016/j.petrol.2020.108125.

[34] Sheikhoushaghi, A., Gharaei, N.Y., & Nikoofard, A. (2022). Application of Rough Neural Network to forecast oil production rate of an oil field in a comparative study. *Journal of Petroleum Science and Engineering*, 209, article number 109935. doi: 10.1016/j.petrol.2021.109935.
[35] Silvia, S., Gilad, Y., Wilson, T.A., Akbari, B., & Furlong, E.R. (2023). Case study: Predicting electrical submersible pump failures using artificial intelligence and physics-based hybrid models. In *SPE middle east intelligent oil and gas symposium* (article number SPE-214462-MS). Al Khobar: SPE. doi: 10.2118/214462-MS.
[36] Sircar, A., Yadav, K., Rayavarapu, K., Bist, N., & Oza, H. (2021). Application of machine learning and artificial intelligence in oil and gas industry. *Petroleum Research*, 6(4), 379-391. doi: 10.1016/j.ptlrs.2021.05.009.
[37] Skillington, K., Crawford, R.H., Warren-Myers, G., & Davidson, K. (2022). A review of existing policy for reducing embodied energy and greenhouse gas emissions of buildings. *Energy Policy*, 168, article number 112920. doi: 10.1016/j.enpol.2022.112920.
[38] Subrahmanya, S.V., Shetty, D.K., Patil, V., Hameed, B.Z., Paul, R., Smriti, K., Naik, N., & Somani, B.K. (2022). The role of data science in healthcare advancements: applications, benefits, and future prospects. *Irish Journal of Medical Science*, 191(4), 1473-1483. doi: 10.1007/s11845-021-02730-z.
[39] Swain, A., Abdellatif, E., Mousa, A., & Pong, P.W. (2022). Sensor technologies for transmission and distribution systems: A review of the latest developments. *Energies*, 15(19), article number 7339. doi: 10.3390/en15197339.
[40] Turchyn, O. (2024). Optimisation of dynamometric data collection and processing to improve the efficiency of neural network diagnostics of a sucker-rod pump. *Bulletin of Cherkasy State Technological University*, 29(3), 55-64. doi: 10.62660/bcstu/3.2024.55.
[41] Tymkiv, D., Hrudz, V., Tutko, R., & Tutko, T. (2024). Forced oscillations of an oil pipeline at an overhead crossing during sequential pumping of various oil products. *Prospecting and Development of Oil and Gas Fields*, 24(1), 32-43. doi: 10.69628/pdogf/1.2024.32.
[42] Wang, J., Xu, C., Zhang, J., & Zhong, R. (2022). Big data analytics for intelligent manufacturing systems: A review. *Journal of Manufacturing Systems*, 62, 738-752. doi: 10.1016/j.jmsy.2021.03.005.
[43] Yatsyshyn, T., Shkitsa, L., Lyakh, M., & Liakh, V.D. (2021). Technological and management solutions to prevent emergencies at oil and gas facilities. *Carpathian Journal of Electrical Engineering*, 15(1), 121-130.
[44] Zhu, H., Zhu, J., Rutter, R., & Zhang, H.Q. (2021). Experimental study on deteriorated performance, vibration, and geometry changes of an electrical submersible pump under sand water flow condition. *Journal of Energy Resources Technology*, 143(8), article number 082104. doi: 10.1115/1.4048863.

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Впровадження нейромережевих технологій для оптимізації управління режимами роботи глибинно-насосної штангової установки

Анотація. Дослідження було проведено з метою виявлення можливостей впровадження нейромережевих технологій для оптимізації управління режимами роботи глибинно-насосної штангової установки (ГНШУ), що сприятиме підвищенню ефективності видобутку нафти та зниженню експлуатаційних витрат. У дослідженні були використані методи аналізу даних та адаптивного управління для оптимізації роботи ГНШУ. В результаті проведеного дослідження було встановлено, що впровадження нейромережевих технологій у систему управління ГНШУ дозволяє суттєво підвищити їх ефективність. Аналіз даних з датчиків установки за допомогою нейромереж дав змогу виявити оптимальні режими роботи, що забезпечують максимальний видобуток при мінімальних витратах енергії. Було розроблено модель прогнозування, яка здатна заздалегідь виявляти потенційні відмови обладнання, що дозволяє знизити ризики аварійних ситуацій і витрати на обслуговування. Також дослідження показало, що адаптивні алгоритми управління на основі штучного інтелекту здатні автоматично коригувати режими роботи ГНШУ залежно від змінних умов, таких як коливання тиску або зміна властивостей видобуваної нафти. Завдяки інтеграції з Інтернетом речей, система отримала можливість здійснювати моніторинг у реальному часі, що підвищує оперативність прийняття рішень. У результаті, запровадження нейромережевих технологій не лише оптимізує процеси видобутку, але й сприяє зменшенню експлуатаційних витрат. Крім того, проведене дослідження виявило, що використання нейромереж у системах управління дозволяє значно зменшити час на налаштування і оптимізацію процесів, що підвищує загальну продуктивність роботи ГНШУ

Ключові слова: модель прогнозування; адаптивні алгоритми; експлуатаційні витрати; аварійні ситуації; потенційні відмови