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THE INDUSTRIAL INTERNET OF THINGS: THE EVOLUTION OF AUTOMATION IN THE OIL AND GAS COMPLEX

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Abstract

The use of modern information technologies, including the Internet of things, contributes to the effectiveness of industrial production in the oil and gas sector. Solutions in this area are constantly developing and provide great advantages in terms of increasing the speed of exploration and detection of oil and gas, increasing oil production and reducing risks to health, human security and environment. The article is dedicated to the study of these issues and the development of a conceptual model of the system based on the industrial internet of things.

Keywords:
Internet of things;
Industrial internet of things;
Cyber-physical systems;
Oil and gas complex;
WSN;
SCADA.

1. Introduction

For the oil and gas complex (OGC), increasing the technical and economic component of extraction processes, their effectiveness, labor productivity, improving the forms and methods of managing oil processes have always been relevant.

Studies on the use of measuring instruments for automatic control of oil production processes consistently started in the mid-20th century. As a result of these studies, positive expert assessments were made on the prospects for the introduction of automation and remote control systems (various primary converters, local devices, etc.) to monitor and control oil and gas production facilities. In the 1980s, advanced oil companies began using SCADA (Supervisory Control and Data Acquisition) systems that solved a number of tasks for data sharing with communication devices with objects and database maintenance. They also began performing real time data processing, displaying the data on the screen in an appropriate and understandable form to the operator and solved some tasks on emergency and alarm signaling.

The technological processes in the OGC take place in three main sectors or, as they are commonly called, Upstream, Midstream and Downstream.

In the first sector, the search for potential hydrocarbon fields (oil and natural gas), exploratory drilling and other work, extracting raw materials, that is, extracting oil or natural gas from the bowels of the earth from offshore platforms or on land.

The second sector covers the stages of transportation and delivery of raw materials to consumers for further processing.

In the third sector, oil or natural gas is processed to produce final products such as gasoline, kerosene, jet fuel, diesel fuel, fuel oil, lubricating oils, liquefied gas, plastics and other materials.

It can be assumed that in each of the described sectors there are a number of critical problems that can be described as follows:

- maintenance of pipes, wells and technological equipment;
- control of the presence and leakage of oil and gas in the drilling, production and transportation processes;
- monitoring the condition of main pipelines (corrosion, pressure) and their security from external intrusions;
- monitoring environment at all stages of technological processes;
- optimization of the operation of all types of pumps (producing, injection, pumping);
- monitoring of failures in technological equipment and minimization of risks;
- increasing productivity while lowering costs.

For example, automation of the drilling process requires a system engineering approach - a closed system of integration of well and surface data obtained in real time with models built before drilling begins. Given the changing conditions, such a system changes the operating settings, such as pump flow, hook weight or drill string rotation speed. In addition, the automated system specifies the model based on real-time data, actually simulating solutions of an experienced drilling engineer, who corrects inaccuracy of available estimations [1].

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The combination of drilling automation with good automation also promises to increase the efficiency of environmental protection, labor protection, and at the same time, to help the operator to ensure economic feasibility of extracting reserves previously unavailable at the modern development level of technology.

On the other hand, currently, the OGC faces new manufacturing problems, especially against the background of a decline in oil prices. An important task is to find modernized new ways to improve results and reduce costs to increase productivity and competitiveness. An important role here is played by the collection of more detailed and accurate information in the manufacturing process and the solution of control problems. The application of IoT technology in the OGC, as in all sectors of industry, has great prospects from the economic point of view. However, the use of this technology makes it necessary to solve a number of scientific, theoretical and technological problems.

In this work, it was attempted to investigate these issues with reference to the Azerbaijani oil company SOCAR.

2. Related works

The automation systems use sensors in oil fields to collect data and monitor the operation of equipment in real time. For example, one drilling rig in an oil field can generate terabytes of data a day, however, only a small part of it is used to make decisions. According to the estimations of McKinsey experts, a typical offshore production platform may have more than 40,000 metadata, although many of them may not be used, i.e., opportunities that could be obtained from the appropriate use of data and technology are not fully used [2]. Not all data are analyzed to predict potential equipment problems. Since oil and gas operations become more complicated and remote, the state of equipment often becomes difficult to see especially on remote offshore platforms or in deep-water areas. The lack of visibility may lead to costly unplanned maintenance or to oil leaks during the accidents caused by equipment failure. Even slight improvements in efficiency can provide significant savings.

Technically sound, timely and immediate solutions to these problems can be considered as important factors that affect the development of the OGC. With the use of modern information technologies, this direction is constantly developing to increase the speed of exploration and detection of oil, increase oil production and reduce the risks to health, security of humans and the environment identified as a result of equipment malfunctions or operator errors. Application of IoT, which is based on sensors, can be taken as a topical choice on the way of implementing the right strategy in gathering information in the OGC.

IoT [3] is a new technology with sensors, computing capabilities, memory and built-in short-range transceivers, which provides a new form of communication between people and things, as well as among things themselves. This evolution is the basis of the structure of modern cyber-physical systems (CPS). CPS consists of numerous components, including those that are different from the functional applications of IoT, controlled by computer algorithms, closely integrated with the Internet and users [4, 5]. These include systems such as Smart Cities, Smart Grids, Smart Factory, Smart Buildings, Smart Houses and Smart Cars, where each object is connected to all others. This should ensure an adaptive, flexible and cost-effective operation.

It can be assumed that the OGC is an information processing factory to some extent that fits into the information technology concept of the CPS. It is a large number of devices with built-in sensors, processors and storage media.

Industrial IoT (IIoT) is a type of IoT for corporate/industrial use is a system of integrated computer networks and connected industrial facilities with built-in sensors and software for data collection and exchange with the opportunity of automated remote control and management without human intervention. The following features characterize the application of IIoT:

- Generation of the big data stream;
- Multilevel data storage;
- Real-time processing;
- Big Data Analytics;
- Forecasting;
- Control and management.

These IIoT capabilities open up new prospects for solving problems in OGC classified by the International Society of Automation as components of industrial systems [6]:

- Safety/Emergency;
- Close loop regulatory control;
- Close loop supervisory;
- Open loop control;
- Alerting;
- Information gathering.

3. Some problems and solutions

The main technical factors of the formation and development of IIoT include the following:

- Evolution of mini, micro and nanosensor production technologies with the ability to collect various information (temperature, pressure, vibration, distance, position, the angle of rotation, the chemical composition of the substance, etc.) from the control and management facilities;
- Transition to IPv6 technology, which removes restrictions on the number of sensors and devices that are connected;
- Introduction of wireless communication technologies that enable to directly extract information from sensors installed in the real measurement zone of parameters of various technological processes;
- Development and improvement of cloud, fog, dew structures that help to store large volumes of information and enable the application of

complex analytical tools such as Big Data, Data Mining, Pattern Recognition, etc.

The key element of IIoT is the sensor network topology [7]. Sensor networks consist of local nodes. Each node is equipped with a sensor for data acquisition, a microprocessor for initial processing of data and development of control actions on actuators and a transceiver for receiving or transmitting data to the next node in the hierarchy.

As a rule, nodes of sensor networks operate in continuous mode or in a mode on demand. In the first mode, the network node uninterruptedly receives the data and sends it online or after the primary processing to the neighboring or central node. In the second mode, the node is in hibernation mode, waiting for the command from the neighboring or central node.

The network component of the IIoT-transceiver node connects it to other nodes and to available computer systems. Depending on the communication needs, such as transmission ranges, data rates, power and battery life, different IoT nodes can be connected using various digital communication methods, including wired or wireless methods. Wired devices are usually connected to the network via an Ethernet connection over a copper or fiber optic cable. Advantages of wired connections are reliability, noise immunity, protection from unauthorized access, high data transfer rates, the ability to supply power at the same time as data transmission, transmission distance. Disadvantages: large volumes and complexity of installation work, a significant amount of equipment and wires

Wireless devices are traditionally connected through the radio frequency spectrum. Bluetooth, RFID, Wi-Fi, ZigBee, and others [8] are usually used at the level of short-range nodes (hundreds of meters within one field), while cellular or satellite communication is used for long-range wireless communications (offshore platforms, main pipeline monitoring systems).

However, the functioning of various manufacturers in the oil and gas industry has some peculiarities. Based on these peculiarities, wireless devices must have the following properties [9]:

- Minimum dimensions and unification;
- Reduced power consumption, autonomous power generation or battery power to reduce maintenance requirements;
- Stable operation in conditions of the complex electromagnetic environment (radio noise, interference, obstacles);
- Restrictions on radio devices when working in fire hazardous areas;
- Prolonged and reliable operation in case of intensive exposure to the environment.

The effective development and implementation of IIoT will depend on the accelerated transition to the Internet protocol version 6 (IPv6). IPv6 removes restrictions on the address space and allows you to have a unique IP address for each sensor, node or device.

However, there are problems associated with some aspects of implementing IPv6, which include security management, the implementation of interfaces that support the dual IPv6 and IPv4 environment and the adoption of new standards.

The development of IIoT technology is related to wireless sensor networks (WSN). Identification of anomalies for monitoring and management in the OGC constitutes the systems based on WSN and SCADA. Each of them has certain limitations. These systems are expensive and inflexible, difficult to scale and have many problems related to data collection, transmission and processing [10, 11].

4. The conceptual model of the system on the base IIoT

Since the emergence and development of microprocessors and network devices, the possibility of using microcontrollers, supplemented by sensors and mechanisms, has been actively studied to ensure greater reliability, efficiency and security of production processes in the OGC (geological exploration, drilling, extraction, processing, transportation, etc.), as there is a high level of financial, environmental and humanitarian risks.

Traditionally, information flows' processing and management in OGC producing enterprises occur on three levels. At the lower level, data monitoring, data collection from sensors and primary processing of information for developing control actions on oil and gas production facilities is carried out in real time with the help of local-group devices. Replacement of conservative and mostly manual control and monitoring devices and the provision of production, transportation and processing processes in the OGC with new, easy-to-install sensors allow for continuous automatic control of technological processes, registration and storage of data, and remote configuration. Thus, it is possible to increase reliability, security, energy efficiency and influence on environmental indicators, such as gas emissions, leaks and spills of primary raw materials. At the next level, decisions are made on optimizing processes, determining the frequency of repair activities to reduce downtime and optimizing maintenance intervals for units and assemblies, ensuring efficient operation, etc. Unplanned downtime due to equipment breakdowns that lead to loss of time and finances can be reduced through the introduction of intelligent maintenance systems. The third level is the level of the company on which the analysis (big data processing) is implemented, which results in the coordination of activities that are part of the company of enterprises and structures to achieve overall efficiency, measures are taken to increase security and reduce risks.

For example, in the «smart field» concept from Schneider Electric, real-time processes within the reservoir are modeled and oil-producing pumps of various modifications are controlled based on data from wired and wireless sensors simulate. Data is stored in the memory of intelligent controllers and is periodically transmitted to the control room, where it is processed by special programs. Due to the introduction of the intelligent system, the downtime

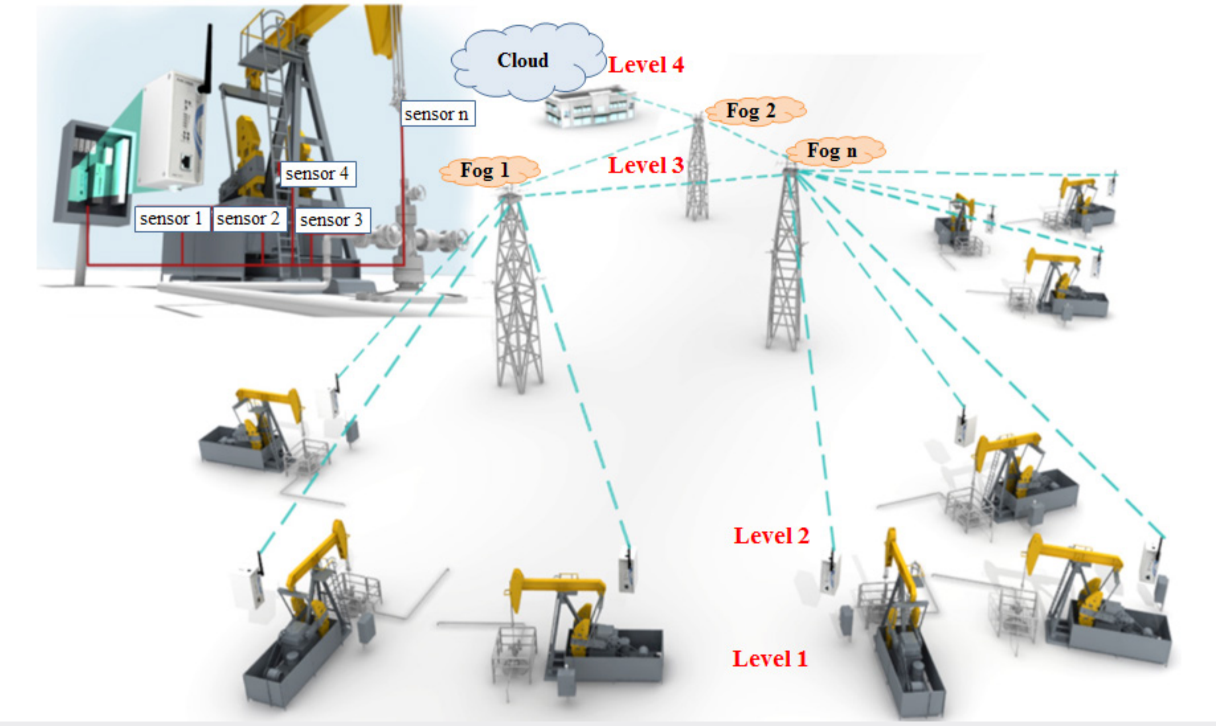

Fig. The conceptual model based on IIoT

of equipment, costs of electricity, steam and water are reduced, and the entire production process is optimized [12].

The conceptual model based on IIoT can be can be represented by four levels (fig.).

As can be seen from figure, the conceptual model is a four-level model, in which:

- *Level one (Level of sensors)*: control object with built-in sensors.
- *Level two (Level of gateways):* gateways controlling data flows. They can also perform primary processing and release of control actions for level one.
- *Level three (Level of clusters):* fog applications and detection of anomalies of real-time data processing.
- *Level four (Level of Data center):* cloud infrastructure, which includes a processing center and a database.

The main stages of technological processes are spatially-distributed. They are grouped into clusters according to certain features; data is processed in clusters without the need to transfer to the cloud. Thus, there is a redistribution of the load from the cloud service to fog computing. To increase the reliability and efficiency of management in case of failures or channel congestion, virtual cross-links are created between the corresponding nodes: gateway-gateway, gateway-fog, and fog-fog.

Thus, when moving from industrial automation systems to systems based on IIoT, the following positive solutions can be achieved:

- Creation of a unified information infrastructure for OGC;
- Integration of various control and management systems in all sectors of OGC;
- Improvement of exploration, extraction, processing, transportation of raw materials and finished products and relationships with customers;
- Determination of optimal operating conditions due to the reduction of unplanned downtime, equipment repairs and costs;
- Compliance with extended requirements for technical and environmental safety;
- Expansion of analytical capabilities;
- Improvement and optimization of management methods and financial policy.

All this suggests that the use of IIoT technology in the SOCAR is of great importance and very relevant at present.

5. Conclusion

The OGC is the leading branch of the national economy of Azerbaijan. The economy of the country and the welfare of the population largely depend on the state of this industry. Currently, the OGC complex faces new production problems, especially against the background of a decline in oil prices. Finding new ways to increase efficiency and competitiveness, improving results and reducing costs is an urgent and important task. Here a special role is assigned to the control and collection of detailed and accurate data and information on the production process. The use of IIoT in these processes is the most optimal strategy. IIoT has the potential capabilities to manage the main processes for the three sectors of the OGC with more efficient and reliable results. The processing of large data collected using new technologies can be performed using the capabilities of cloud technologies, Big Data and Data Mining technology, and the obtained results will provide operational and look-ahead control, thereby increasing production efficiency.

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References

1. *W.Aldred, J.Bourque, M.Mannering, et al.* Drilling automation //Oilfield Review. -2012. -Vol.24. -No.2. -P. 18-27.

2. *S.Martinotti, J.Nolten, J.A.Steinsbo*. Digitizing oil and gas production. McKinsey & Company, 2014. https://www.mckinsey.com/industries/oil-and-gas/our-insights/digitizing-oil-and-gas-production

3. Recommendation ITU-T. Y.2060. Overview of the internet of things. 06/2012. https://www.itu.int/rec/T-REC-Y.2060-201206-I.

4. *R.Alguliyev, Y.Imamverdiyev, L.Sukhostat.* Cyber-physical systems and their security issues //Computers in Industry. –2018. -Vol.100. -P. 212-223.

5. *E.A.Lee*. Cyber-physical systems: Design challenges //Proceedings of the 11th IEEE International Symposium on Object-Oriented Real-Time Distributed Computing (ISORC). –2008. -P.363-369.

6. *R.Mohsin, A.Nauman, L.Hoa, et al.* A critical analysis of research potential, challenges, and future directives in industrial wireless sensor networks //IEEE Communications Surveys and Tutorials. -2018. -Vol.20. -Issue 1. -P. 39-95.

7. *B.A.McAdams.* Wireless sensor networks – applications in oil & gas. https://www.remotemagazine.com/main/articles/wireless-sensor-networks-applications-in-oil-gas.

8. *P.Zand, S.Chatterjea, K.Das, P.Havinga*. Wireless industrial monitoring and control networks: The journey so far and the road ahead //Journal of Sensor and Actuator Networks. -2012. -Vol. 1. -P. 123-152.

9. *M.Reza Akhondi, A.Talevski, S.Carlsen, S.Petersen*. Applications of wireless sensor networks in the oil, gas and resources industries //Proceedings of th 24th IEEE International Conference In Advanced Information Networking and Applications (AINA). -2010.

10. *S.A.Boyer.* SCADA: supervisory control and data acquisition. International Society of Automation, 2004.

11. *W.Z.Khan, M.Y.Aalsalem, M.Kh.Khan, et al.* A reliable internet of things based architecture for the oil and gas industry //Proceedings of the 19th International Conference on Advanced Communication Technology (ICACT). -2017. -P. 705-710.

12. *M.Cherkasov.* Schneider electric. The concept of «Smart Field». http://portal-energo.ru/articles/details/id/950.

Промышленный интернет вещей: эволюция автоматизации в нефтегазовом комплексе

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Реферат

Использование современных информационных технологий, в том числе интернета вещей, способствует повышению эффективности промышленного производства в нефтегазовом секторе. Решения в этой области постоянно развиваются и дают большие преимущества в плане увеличения скорости разведки и обнаружения нефти и газа, увеличения добычи нефти и снижения рисков для здоровья и безопасности человека и окружающей среды. Статья посвящена изучению этих вопросов и разработке концептуальной модели системы, основанной на промышленном интернете вещей.

Ключевые слова: интернет вещей; промышленный интернет вещей; киберфизические системы; нефтегазовый комплекс; WSN; SCADA.

Sənaye əşyalarının interneti: neft-gaz kompleksində avtomatlaşdırmanın təkamülü

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Xülasə

Müasir informasiya texnologiyalarının, o cümlədən əşyaların internetinin istifadəsi neft-qaz kompleksində istehsalın effektivliyinin artırılmasında mühüm rol oynayır. Bu sahədə həllər daim inkişaf edir və karbohidrogen ehtiyatlarının kəşfiyyatı və aşkarlanması sürətinin artırılması, neft hasilatının inkişaf etdirilməsi və insan sağlamlığı, təhlükəsizliyi və ətraf mühit üzrə risklərin azaldılması baxımından böyük üstünlüklər verir. Məqalə bu məsələlərin öyrənilməsinə və sənaye əşyalarının İnternetinə əsaslanan sistemin konseptual modelinin işlənməsinə həsr olunub.

Açar sözlər: əşyaların interneti; sənaye əşyalarının interneti; kiber-fiziki sistemlər; neft-qaz kompleksi; WSN; SCADA.