APPLICATION OF INDUSTRY 4.0 MODEL IN OIL AND GAS COMPANIES

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Review Paper

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Although the concept of Industry 4.0 was defined a decade ago, experts have only been talking about the "Oil and Gas 4.0" model in the last few years. Experts in this industry agree that the "Oil and Gas 4.0" model in use, based on the digitalization and intelligence of the oil and gas industry, can bring huge benefits to the company. However, the "Oil and Gas 4.0" model is still in its infancy, but applications in areas such as big data (BDA), industrial Internet of Things (IIoT), or analysis of typical oil and gas industry chain application scenarios through examples, such as an intelligent oil field, an intelligent pipeline, and an intelligent refinery, make today's challenges real. So the essence of the "Oil and Gas 4.0" model is a data-driven intelligence system based on high digitization. This paper provides an overview of the state and development of the Industry 4.0 concept in the Oil and Gas Industry.

Keywords: Industry 4.0; Oil and Gas; Development; Application.

INTRODUCTION

The Industry 4.0 model was used a deep integration of advanced technologies and informatics (Gilchrist, 2016; Mittal et al., 2017), and the basic framework of Industry 4.0 is shown in Figure 1 (Hankel et al., 2015), and has four main areas: smart factory, smart manufacturing, smart logistics, and smart services. The smart factory operates on a digital factory platform, using the Internet of Things (IoT), big data analysis (BDA), and monitoring technology, which improves information management and thus improves the management of manufacturing processes. Smart manufacturing is supported by tools and techniques of artificial intelligence, which in combination with data on 3D models of products, manufacturing, and equipment, achieve multidimensional intelligent manufacturing, from an IT point of view. Smart logistics uses also intelligent technology to support the logistics system to assess and solve transport problems in logistics, based on reasoning, deep learning, and decision making, based on the aim of optimizing these processes. Smart services also use advanced technology for Industry 4.0 and support all needs of users. In this way, we integrate all elements of Industry 4.0 into manufacturing and business chains.

In the developed country, oil and gas technology in the last half century, each decade has been characterized by major changes, as there have been major innovative technology, as shown in Figure 2 (Jinhua et al., 2016).

At the Abu Dhabi International Petroleum Exhibition and Conference - ADIPEC) in 2018, Dr. Sultan Ahmed Al Jaber, CEO of the Abu Dhabi National Oil Company (ADNOC) Group, presented for the first time the concept of the "Oil and Gas 4.0" model (The National, 2022). In the "Oil and gas 4.0" model, the main goal is to use advanced IT technology to improve added value in this industry. According to today's statistics, 30% of oil and gas companies are "new" or "research" in the digital process. It is commonly thought that the oil and gas industry has a leading role in the application of new technologies. However, the reality is different, because only certain groups in

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this industry can apply them, such as robots and satellites. Therefore, we can say that they are at the level of "examples of good practice", but there is no interdisciplinary integration at the level of branch or industry.

In the period from 2010 to 2020, the application of new technologies related to Industry 4.0 includes the analysis of big data, generated by intelligent sensors, so that for a decade (2020 – 2030.), the application of new technologies related to the main elements Industries 4.0.

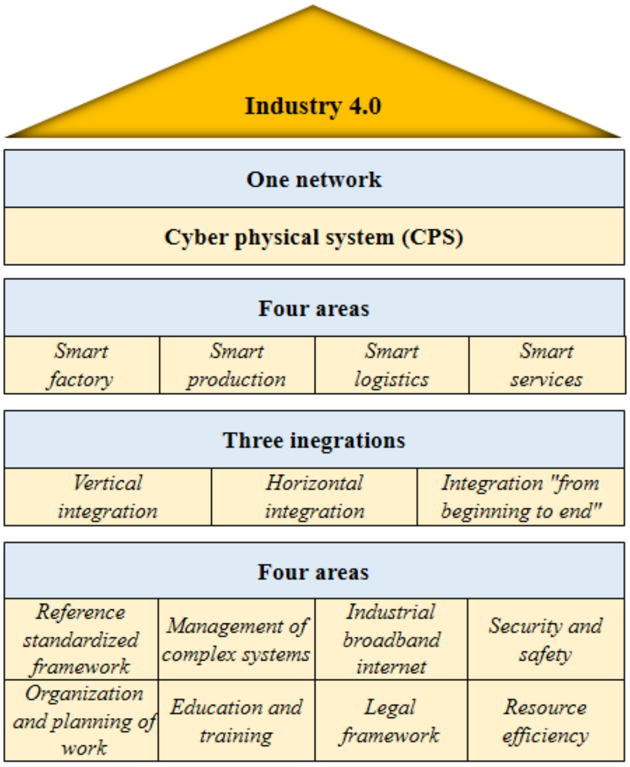

Figure 1: Strategic frameworks of the German Industry 4.0 model (Hankel & Rexroth, 2015)

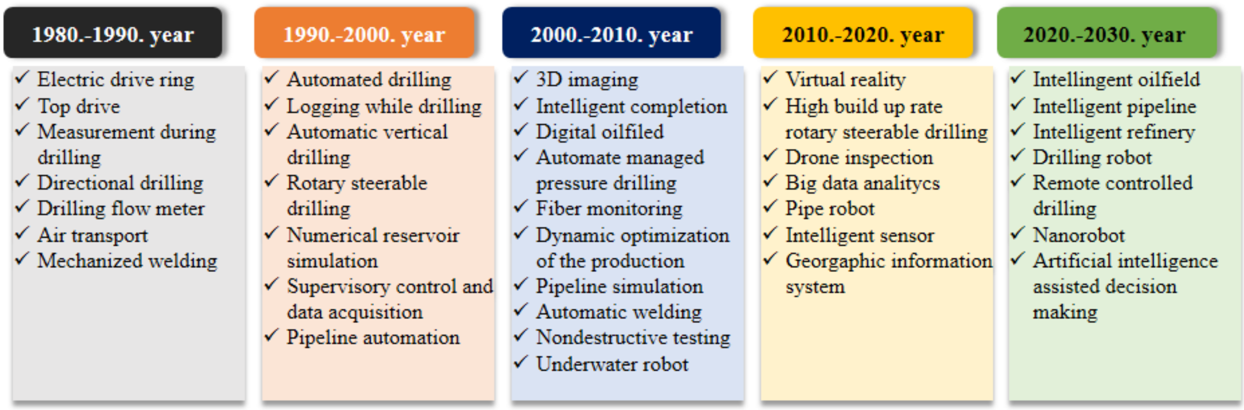

Figure 2: Key elements of development and application of technological innovations in the oil and gas industry in the last half century (Jinhua et al., 2016)

METHODOLOGY

When we analyze the chain of the oil and gas industry, we can divide it into the following whole: (i) exploration, extraction, and storage, (ii) long-distance transport, and (iii) processing and sale of oil and gas products (Lu et al., 2019b). Starting from the above division, the oil and gas system and in the context of the era "Oil and gas 4.0" we can have the following elements in it, Figure 3 (Lu et al., 2019a).

For the first whole of the Industry 4.0 model for "Oil and gas 4.0", today's concept of digitization as the basis of this model includes the following activities (BDO, 2022): (a) exploration and seismic recording of drilling is a process that has long been applied and supported by BDA and 3D perspective and simulation models. Today, a new generation of seismic recording is increasingly used, such as 4D models, which integrate well production data and thus map changes in oil and gas levels in them. This concept has the ability to more accurately determine the number of resources and life of each drilling, which is extremely important for this research; (b) digitization of the drilling process is based on the use of data from intelligent sensors, which determine the drilling methods that give the best mixture of sand, water, and chemicals to achieve the greatest performance of the well, thus increasing productivity and reducing costs. Drilling equipment with built-in smart sensors for data collection allows their integration with various drilling tools, which allows analysis and simulation to obtain a complete picture of the company's production, from all aspects

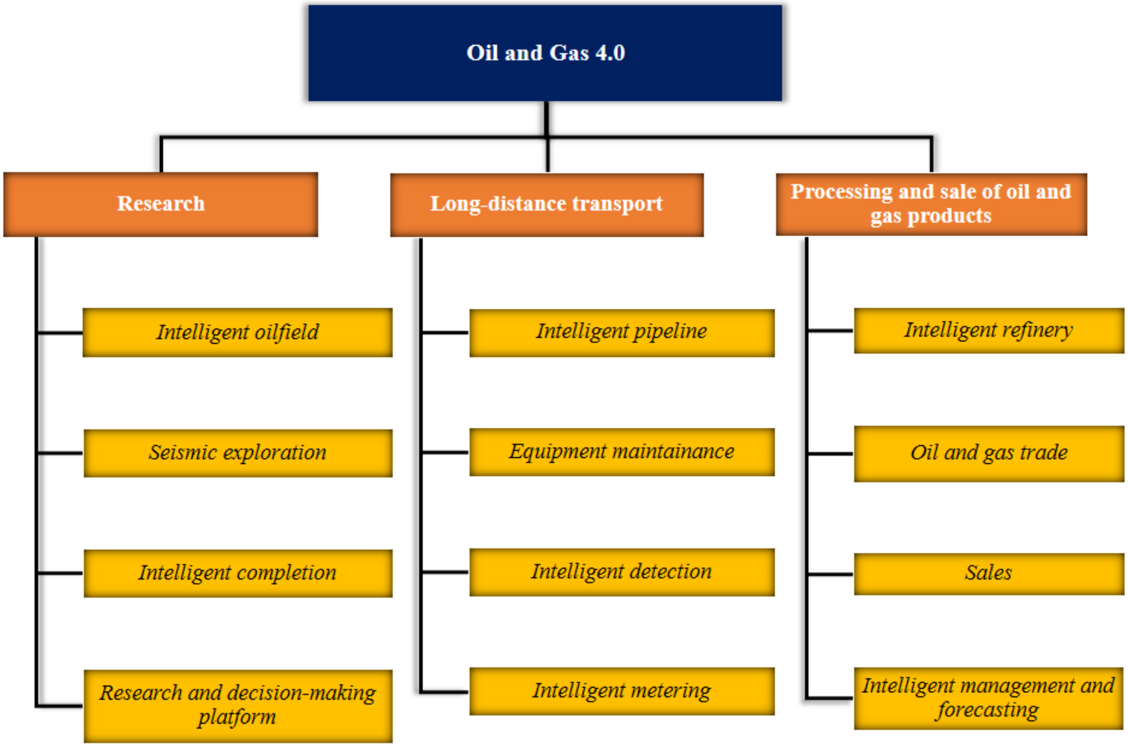

Figure 3: Industry Context 4.0 for the "Oil and gas 4.0" Model (Lu et al., 2019a)

The second part is related to storage – an important part of digital transformation, which used data management for monitoring systems for: inventory levels, temperature control, as well as transport, namely: (a) the use of smart sensors on wagons and tracks, which will provide real-time geolocation data and monitor key transport safety parameters, to minimize the risk of jumping off the rails, as well as (b) also, smart sensors can detect leaks early, as well as monitor the following parameters in the pipeline infrastructure: pressure, temperature, and deformation.

The third whole refers to refineries and the chemical industry based on oil and gas, so the production of smart sensors, improves the monitoring of safety and functionality of all processes. The second part is the distribution of finished products, where predictive analysis comes to the fore, which allows the company to predict demand with greater precision, constantly exchanging data through the supply chain and automating production levels.

It is important to note that the digitalization of supply chains also improves processes and reduces costs in the organization. But together, innovations based on digitalization will transform this sector. The real power of digitalization and the key point of Industry 4.0 is the way in which separate technological processes are connected and communicated, to build a new data ecosystem for the "Oil and Gas 4.0" model.

ELEMENTS OF INDUSTRY 4.0 FOR OIL AND GAS

Big data and their analytics, Figure 4. Big data is characterized by its quantity, diversity, and speed of generation, and therefore requires new techniques of data processing and analysis (Mittal et al., 2019). In industrial production, a large amount of data is generated, which should be stored, optimized, and used to: improve product quality, save energy, make decisions, and improve services. To achieve this, it is necessary to develop and apply models for these areas.

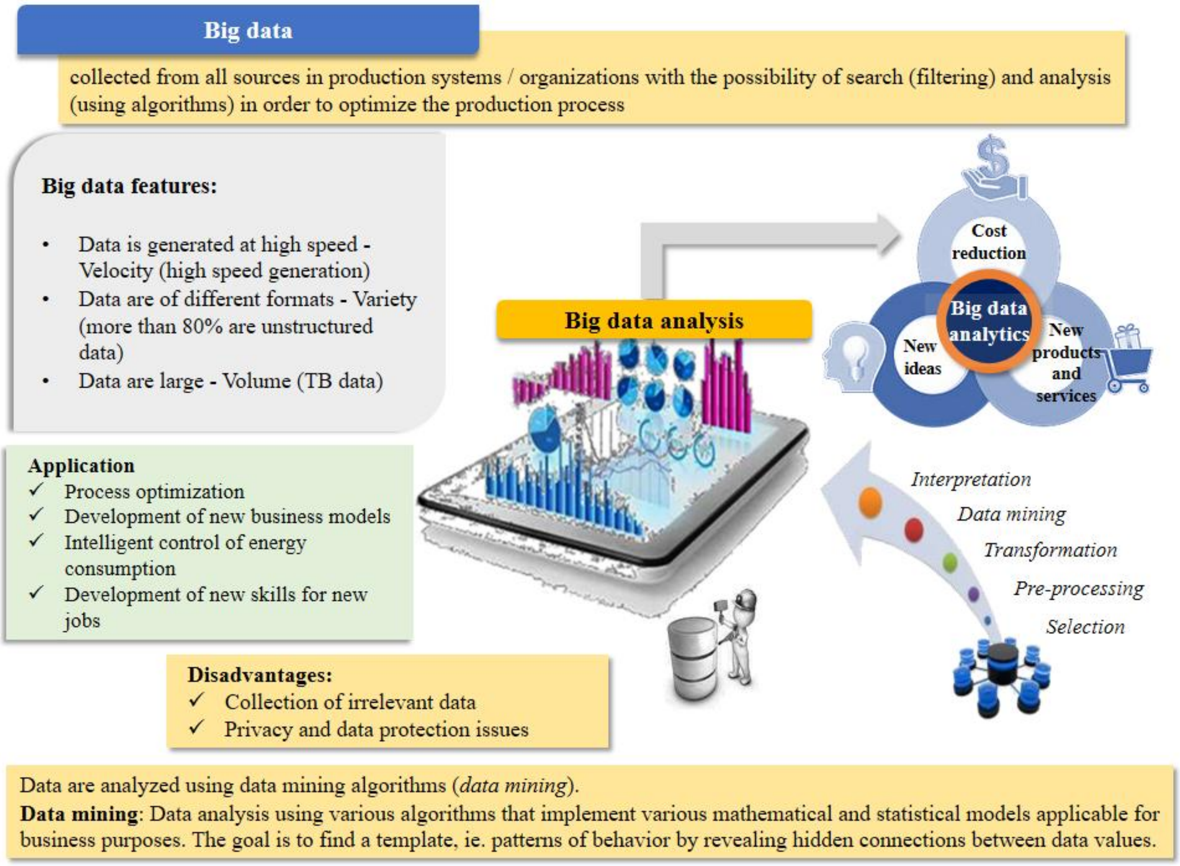

Figure 4: Big data and their analysis

Big data analysis is a technology that can be used to analyze large data sets, including online data, which are difficult to analyze by traditional methods. (Mittal et al., 2019). Data analytics deals with the transformation of large volume, diversity, speed of collection, and truthfulness of data in the Industry 4.0 model, including their simulation, visualization, as well as real-time communication with users. Machine learning also refers to the application of large amounts of data in the model, especially the application of the model of learning based on examples.

The application of BDA in the oil and gas industry began recently. The facts show that a large amount of data is generated in this industry every hour, per element, Table 1 (Lu et al., 2019a).

Table 1: An overview of the volume of data generated in this industry (Lu et al., 2019a)

Area	Data volume
Driling data	0.3 GB/well/day
Electric submersible pump monitoring	0.3 GB/well/day
Wireline data	5 GB/well/day
Fiber optic data	0.1 GB/well/day
Seismic data	100 GB/survey
Plant process data	4-6 GB/day
Pipeline data	1.5 TB/600 km
Plant atmospheric data	0.1 GB/day
Vibration data	10 GB/well/year
Plant operational data	8 GB/year

When this data is used properly, it can produce great benefits, using big data applications. The size of the data is usually reached PB (1024TB) or EB (1024PB). This data includes online tracked information as well as images. For data collection, analysis and management, the following are used here: advanced sensor technologies, big data hardware, AI and ML analysis tools, as well as cloud computing. Using Enlift statistics (Enlyft, 2022) the following platforms for BDA are most commonly used: Apache Hadoop, Informatica, and Apache Hbase because they take up about 50% of the market share.

Industrial Internet of Things (IIoT). IIoT is used as an IoT in the industry. It enables the realization of mobile communications, connecting sensors, and enables intelligent process analysis in this industry as well. It collects, monitors, and analyzes data, creating the conditions for organizations to make fast and smart decisions (Kalunga, 2020).

At present, a large number of companies in this field do not exchange information or transfer information promptly, which is not suitable for assessing supply and demand in the supply or sale chain, nor is it suitable for managing this sector. IIoT can make the exchange of information more practical and optimize the global level supply chain of those companies, especially from a maintenance perspective. That is why these companies today use IIoT for predictive maintenance and monitoring of plant conditions. IIoT can help protect the environment, as it is efficient in collecting information and uses less energy, and quickly locates oil and gas leaks. In (Khan et al., 2017) were given the first IoT operational architecture for this industry, it has three modules: a smart facility, a gate, and a smart center. The first module includes smart sensors, which are located on the plants. The smart center performs BDA analysis of the collected data. The gate is the link between the smart facility and the smart center. Today, large numbers of an organization are also researching the building of the IIoT platform, following this model: ABB Ability, General Electric (GE), Cisco IoT, and Siemens.

Digital twin. This is a model in development for digitization processes in the Industry 4.0 model. Researchers and practitioners in the industry define it differently, primarily from an application perspective. This is a digital simulation in virtual space, physical entities of the plant, interconnected by sensors (Mayani et al., 2018; Poddar, 2018). The Digital twin model of technological process (including processes in the oil and gas industry) is a feedback model "physical world-digital world-physical world " (Pronier, 2018). The realization of digital twins integrates data from actuators, internal loop sensors, and the results of their analyzes. All data captured by the sensor are combined with previously collected plant data to achieve data of transfer from the physical to digital worlds through their integration technology, and stages in building digital twin architecture are: creating, communicating, collecting data, analyzing data, reviewing, and use.

Today, there are already digital twin solutions for oil drilling, for example (Halliburton, 2017), for the following areas: real-time modeling, drilling simulator, hydraulic and temperature simulations of drilling, software platforms for control and monitoring of dynamic and connection of real-time drilling process, display of current drilling condition with predictions of drilling properties.

Wireless communication technologies. Starting from the fact that the most common workplace in this industry is remote, so incidents can be dangerous to the environment, then the application of new communication technologies is extremely important. Research has shown how extremely important the communication environment is because it can improve the efficiency of work and maintenance and reduce production and maintenance costs. At the moment, wireless communication technologies are used more: Wi-Fi, Zig-Bee, RFID, Bluetooth, ultra-broadband (UVB), communication nearby (NFC), general radio service packages (GPRS), and infrared data connectivity (IrDA), and their common parameters are given in Table 2 (Harwood, 2020).

Today, this technology is used for: monitoring drilling, transport (pipeline, train), refineries, and gas stations, most often the following parameters: pressure, temperature, volume, etc.

Augmented reality (AR). AR is a technique for determining the position and angle of real-time camera images and adding matching images, 3D models, or videos (Azuma et al., 2001). It is important to say that this system works in real time, integrating the real and virtual world. AR systems have specific hardware and software support, which must work in real time. Three different models of AR systems are used: optical perspective, video perspective, and monitor. Today, AR technology in this industry is mostly used for: training operators to work in complex jobs, planning and performing maintenance, and for visual support of various training.

Table 2: Overview of wireless communication technology models (Harwood, 2020)

Wireless technology	Transmission distance (m)	Frequency band (GHz)	Communication quality	Hardware cost
Zig-Bee	10-100	2.4	High	Low
Bluetooth	10-20	2.3-2.485	High	Medium
Wi-Fi	300	2.4	High	Medium
RFID	5-10	1-100	Limited	Low
UWB	<10	3.1-10.6	High	Very High
NFC	<0.1	0.01356	Medium	Low
GPRS	20000	0.835-0.96	Medium	High
IrDA	1	Very high	High	Low

Blockchain technology. This is a model for managing transactions through transparent reliable rules for constructing data structures. Generated blockchain blocks cannot be falsified and cannot be changed. They can be monitored in a peer-to-peer (P2P) network environment. This concept encrypts transactions, as well as their distribution on multiple computers (Andoni et al., 2019). Each member of the network checks transactions using a common algorithm, assigns a hash value, and if any transaction information changes, an error is reported. When a block is verified, it is connected to a previously verified block, creating a chain. A transaction can now be completed, and this happens when two parties confirm the same. At this level of development, this technology has the following ownership classes: private, consortium, and public blockchain, (Lu et al., 2019a).

This technology is used in this industry to increase the security and transparency of goods and equipment services transactions, which means that it increases cyber security and surveillance, as well as improves trade and decision-making, (Lu et al., 2019b).

Other technologies of Industry 4.0. The above technologies of Industry 4.0 are increasingly complementing other technologies in this area: 3D printing, autonomous robots, cyber security, and system integration (Chen et al., 2018; Mittal et al., 2017).

Autonomous robot: Robots are increasingly used in this industry, especially for the inspection of pipelines and equipment, as well as for their repair. Drones are also increasingly being used. (Mashreq, 2019).

3D printing: This is an important technology for this industry, especially in the production of spare parts. (Mashreq, 2019).

Cyber security technology: Cyber security is especially important in support of the BDA concept in this industry. (Mashreq, 2019).

System integration: This technology mostly supports better planning and management of different parts of the supply chain in this industry. (Hankel & Rexroth, 2015).

Finally, artificial intelligence (AI) has great application in this concept, especially as a support to the BDA model. It is also important to say that AI has great potential for application in production (predictive maintenance in particular) and management and decision making. For example, Shell has implemented an intelligent drilling solution using Shell GeodesicTM, which collects real-time drilling data and makes decisions automatically (Microsoft, 2018); companies from this industry use artificial intelligence algorithms to predict and allocate resources (oil and gas), as well as to apply BDA analysis in predictive maintenance.

Finally, when summarizing the development and application of the "Oil and Gas 4.0" model, we can arrive at a summary analysis, as given in Table 3. (Lu et al., 2019a).

Table 3: Examples of application of elements of Industry 4.0 in the model "Oil and Gas 4.0" (Lu et al., 2019a)

Element	Scope of application	I4.0 technology	Example
Well	Seismic exploration	Big data	Sinopec's ''p-Frame''
	Intelligent oil field	IIoT, wireless communication technologies, big data	BP's ''Field of the Future''
Pipeline	Inteligent pipeline	Big data, IIoT	GE and Accenture's ''Intelligent Pipeline Solution
	Equipment maintenance	Digital twin, AR, portable unit	Floating production storage and offloading (FPSO) ship
Refinery	Intelligent refinery	Digital twin, AR, big data	Sinopec Jiujiang Company's intelligent refinery
	Oil and gas trade	Blockchain technology	Liquefied natural gas (LNG) trade

CONCLUSION

The analyzes presented in this paper allow us to define the following conclusions (Lu et al., 2019a): (a) the core of the "Oil and Gas 4.0" model is not limited to digitalization, but intelligence, ie creation, monitoring, and decision-making based on data, (b) difficulties in implementing the Oil and Gas 4.0 model are not only the development of an integrated platform, but also the integration of the industry's technologies and elements of Industry 4.0, and (c) the Oil and Gas 4.0 model can improve and make oil and gas production more efficient, environmentally friendly and safer, and make the whole chain in this industry more traceable and transparent.

REFERENCES

Andoni, M., Robu, V., Flynn, D., Abram, S., Geach, D., Jenkins, D., . . . Peacock, A. (2019). Blockchain technology in the energy sector: A systematic review of challenges and opportunities. *Renewable and Sustainable Energy Reviews, 100*, 143-174. https://doi.org/10.1016/j.rser.2018.10.014

Azuma, R., Baillot, Y., Behringer, R., Feiner, S., Julier, S., & MacIntyre, B. (2001). Recent advances in augmented reality. *IEEE Computer Graphics and Applications, 21*(6), 34-47. https://doi.org/10.1109/38.963459

Chen, B., Wan, J., Shu, L., Li, P., Mukherjee, M., & Yin, B. (2018). Smart Factory of Industry 4.0: Key Technologies, Application Case, and Challenges. *IEEE Access, 6*, 6505-6519. https://doi.org/10.1109/access.2017.2783682

Enlyft. (2021). Market Share of Big Data products. https://enlyft.com/tech/big-data

Gilchrist, A. (2016). *Industry 4.0: The Industrial Internet of Things* (1 ed.). Berkeley, CA: Apress. https://doi.org/10.1007/978-1-4842-2047-4

Halliburton (Producer). (2017, February 2022). Digital Transformation: Smart and Connected Oilfield Operations. https://usea.org/sites/default/files/event-/3.6%20Digitalized%20Oil%20and%20Gas%20Fields.pdf

Hankel, M., & Rexroth, B. (Producer). (2015, February 2022). *Industrie 4.0: The Reference Architectural Model Industrie 4.0 (RAMI 4.0)*. https://www.zvei.org/fileadmin/user_upload/Themen/Industrie_4.0/Das_Referenzarchitekturmodell_RAMI_4.0_und_die_Industrie_4.0-Komponente/pdf/ZVEI-Industrie-40-RAMI-40-English.pdf

Harwood, T. (2020, February 2022). *IoT Standards and Protocols*. https://www.postscapes.com/internet-of-things-protocols/

BDO. (2022, February 2022). *How Industry 4.0 is Transforming the Oil & Gas Supply Chain.* https://www.bdo.com/getattachment/772e764b-83ca-4783-b323-3a5eed10a068/attachment.aspx?NR-Oil-Gas-Industry-4-0-Supply-Chain_4-18_WEB.pdf

Jinhua, Y., Maoxin, Q., Hongna, H., Xu, Z., & Xiaoxia, G. (2016). Intelligence – Oil, and Gas Industrial Development Trend. *Petroleum Science and Technology Forum, 35*(6), 36-42. https://doi.org/10.3969/j.issn.1002-302x.2016.06.008

Kalunga, J., Tembo, S., & Phiri, J. (2020). Industrial Internet of Things Common Concepts, Prospects and Software Requirements. *International Journal of Internet of Things, 9*(1), 1-11. https://doi.org/10.5923/j.ijit.20200901.01

Khan, W. Z., Aalsalem, M. Y., Khan, M. K., Hossain, M. S., & Atiquzzaman, M. (2017). A reliable Internet of Things based architecture for oil and gas industry *2017 19th International Conference on Advanced Communication Technology (ICACT)* (pp. 705-710). https://doi.org/10.23919/ICACT.2017.7890184

Lu, H., Guo, L., Azimi, M., & Huang, K. (2019a). Oil and Gas 4.0 era: A systematic review and outlook. *Computers in Industry, 111*, 68-90. https://doi.org/10.1016/j.compind.2019.06.007

Lu, H., Huang, K., Azimi, M., & Guo, L. (2019b). Blockchain Technology in the Oil and Gas Industry:

A Review of Applications, Opportunities, Challenges, and Risks. *IEEE Access, 7*, 41426-41444. https://doi.org/10.1109/access.2019.2907695

Mashreq (Producer). (2019, February 2022). Disrupting Oil & Gas: The new technologies that are transforming the world's energy supplies. https://www.meedmashreqindustryinsight.com/wp-content/uploads/2019/02/DISRUPTING-OIL-GAS_Report-2-web.pdf

Mayani, M. G., Svendsen, M., & Oedegaard, S. I. (2018). *Drilling Digital Twin Success Stories the Last 10 Years*. Paper presented at the SPE Norway One Day Seminar. https://doi.org/10.2118/191336-MS

Microsoft. (2018, September 20). Shell expands strategic collaboration with Microsoft to drive industry transformation and innovation https://news.microsoft.com/2018/09/20/shell-expands-strategic-collaboration-with-microsoft-to-drive-industry-transformation-and-innovation/

Mittal, S., Khan, M. A., Romero, D., & Wuest, T. (2017). Smart manufacturing: Characteristics, technologies and enabling factors. *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture, 233*(5), 1342-1361. https://doi.org/10.1177/0954405417736547

Poddar, T. (2018). *Digital Twin Bridging Intelligence Among Man, Machine and Environment*. Paper presented at the Offshore Technology Conference Asia. https://doi.org/10.4043/28480-MS

Pronier, J.-Y. (2018, February 13). How Digital Twins relate to Gartner's top 10 strategic trends. *Unlocking Business Advantage with Digital Twins* https://vantiq.com/blog/unlocking-business-advantage-with-digital-twins/

The_National (2022, February). Oil & Gas 4.0 https://oilandgas4.thenational.ae/

PRIMENA MODELA INDUSTRIJE 4.0 U NAFTNIM I GASNIM KOMPANIJAMA

Iako je koncept Industrije 4.0 definisan pre deceniju, stručnjaci tek poslednjih nekoliko godina govore o modelu „Nafta i gas 4.0". Stručnjaci su saglasni da model „Nafta i gas 4.0" u upotrebi, zasnovan na digitalizaciji i inteligenciji naftne i gasne industrije, može doneti ogromne koristi kompaniji. Međutim, model „Nafta i gas 4.0" je još uvek u razvoju, ali primene u oblastima kao što su: veliki podaci (eng. Big Data Analytics), industrijski internet stvari (eng. Industrial Internet of Things - IIoT) ili analiza tipičnih scenarija primene lanca industrije nafte i gasa kroz primere, kao što su inteligentno naftno polje, inteligentni cevovod i inteligentna rafinerija, čine današnje izazove stvarnim. Suština modela „Nafta i gas 4.0" je sistem inteligencije vođen podacima zasnovan na visokoj digitalizaciji. Ovaj rad daje pregled stanja i razvoja koncepta Industrija 4.0 u okvire industrije nafte i gasa.

Ključne reči: Industrija 4.0; Nafta i gas; Razvoj; Primena