Smart Solutions in the Oil and Gas Industry: A Review

Redouane Sarrakh, Suresh Renukappa, Subashini Suresh, and Saeed Al Nabt

Abstract—A great importance had been given to sustainable development in the past decades, especially within the oil and gas industry, companies around the world are expanding their strategies in order to follow the current trend and information and Communication Technology are considered as a key factor for achieving sustainable development. That along with the constant technological development the oil and gas sector is experiencing had forced the industry to adapt smart solutions in order to meet the market's changing demand and improve the efficiency of its operations. With the goal of studying examples of smart solutions within the oil and gas industry from a general perspective, a literature review was conducted and the main characteristics and attributes of each solution had been exploited. Smart solutions gained a great appreciation in the industry, but their application is still modest, and the industry did not benefit from it in a meaningful way and has little impact on companies' business model.

Index Terms—Smart solutions, oil and gas, smart fields, big data, blockchain.

I. INTRODUCTION

The huge expansion of human activities the world had experienced during the last century had certainly went with the minimum public notice [1] compared to nowadays. It was not until the globalization era that the attention was brought to the potential detrimental impact of human's development on the planet [2]. Making from the continuous anthropogenic activities hard not to be noticed. The industrialized economy had transformed the lifestyle of the worldwide population by improving the standards of living and increasing prosperity. Carbon-based economies had driven humanity to invest more into technology and innovation, making their lives easier and more efficient. However, humanity's development has a downside to it, as it has been discussed heavily in the literature and it is seen clearly in the environment [3]. The increase of the earth's core temperature, the growing number of pollutant-based particles in the air and the continuous threats to the marine world are only a few examples amongst a lot of human's activities' impact on the environment. Therefore, decision-makers are required to make huge efforts to contain these problems before intensifying and resulting in catastrophic consequences for the planet.

Sustainable development could be seen as a reactive response to the unhealthy regime of human activities and how they are carried out. The concept had been getting a lot of attention, especially after the Brundtland report in 1987, and is since then became the focus of decision makers all over the world [4]. However, human's development became very dependent on unsustainable forms of resources and the shift towards an economy with low dependence on fossil fuel would not be an easy task. Information and Communication technology (ICT) are considered as key accelerator and success factor in helping humanity achieve sustainable development [5], as it plays a vital role in energy intensity reduction and improves energy efficiency throughout the economy [6]. Furthermore, the Global Information Infrastructure Commission (GIIC) confirmed that the adaptation of ICT has the ability to change businesses and consumers' behaviour, helping thus in achieving sustainable development without compromising the economy [7].

Information and Communication technology is currently taking the driving seat in modern business practices, it introduced new industries, expanded ones and reshaped others [8]. Rands [9] argues that technology would play the role of a differentiator to decide the long-term success and survival of companies. ICT application within the oil and gas industry is crucial for its survival, especially since a large of its process operations depend heavily on ICT, such as automation, control tools and inter-organizational communication. The sector had spent around $700 million on IT technology in 2014 [9], compared to the defence agencies that spent $968 million. Both Mathieson [10] and Westwood [11] argued that operations within the oil and gas industry have become more complex and expensive over the past few decades, due the depletion of a big number of conventional oil and gas reserves, the tendency of petroleum companies to move their production from onshore to offshore locations and the rise of nonconventional reserves. An example of the IT technologies' impact on the oil and gas sector is the emergence of process control tools back in the 1990s, as it ensured an efficient production of oil and gas at the time [10]. Another example would be its impact on the US shale fields, it is predicted that shale 2.0 would eventually cost between $5-$20 per barrel, which is the same cost that Saudi Arabia produces its oil.

ICT is amongst the smart solutions that were introduced to the industry in the hopes of improving production while achieving sustainable development. The term "smart solutions" have been gaining a lot of attention within the industry and literature in recent years, because of its importance and great potential impact on the oil and gas industry, still a lot of confusion is surrounding this concept [12]. This paper aims to study the concept of smart technology within the petroleum industry from a general point of view. A number of the smart solutions would be reviewed. The methodology of the paper includes a thorough review of the available literature on the subject, carried out up to date.

II. OVERVIEW ON SMART SOLUTIONS IN THE OIL AND GAS INDUSTRY

The literature research based on this paper is conducted over a scope of textbooks and peer reviewed papers published in academic journals and available in the following database: Science Direct, ProQuest, Google Scholar, Dawsonera and Scopus. Dissertations, web papers and unpublished research have not been considered within the review of the literature. Only research in English languages are taken into consideration. An important work had been done in Brazil, Russia, Norway and other countries in their native languages, but it was agreed to consider only research based on English, seeing the remarkable academic and practical work done in English language. The following key words and titles were used in the search within the mentioned databases: "Smart technology in the oil and gas industry", "Big Data in petroleum industry", "Smart solutions in the oil and gas industry", "smart wells", "Smart fields", "Digital oilfields" and "Intelligent energy".

A. Big Data

Big Data is a term that incorporates the employment of new techniques and technology to capture, process, analyse and visualise large and complex sets of data in a practical timeframe that is beyond the capacities of standard IT technologies [13]. The advanced technologies used to store, manage, analyse and visualise the data are called Big Data Technologies. The sharp decrease of data storage costs coupled with a constant growth in computer processing speeds and several mathematical breakthroughs were amongst the technological developments that lead to the birth of Big Data. The main characteristics of Big Data, which differs from traditional approaches, are what is known as the 3 Vs: Volume, Velocity and Variety [14]. IBM went on and added the fourth and fifth Vs, Veracity and Value that covers the quality and value of the data [15], as shown in Fig. 1. For industries, the move for Big Data would mean a shift from the traditional approaches of data collection and analysis, that were mainly based on very accurate sampling from a wider population because of either technological or financial barriers. Therefore, a more flexible approach towards larger volumes of data with a great tolerance to vagueness and messiness [16].
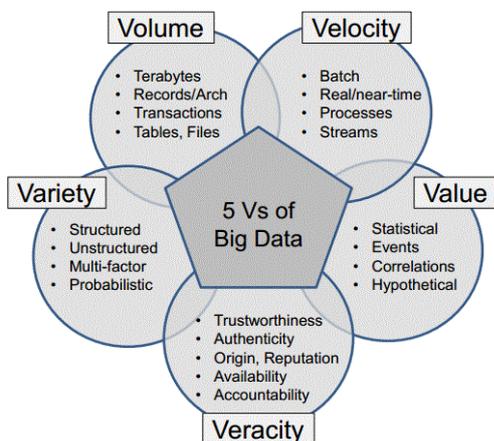

Fig. 1. 5V's of Big Data [15].

Large data sets are not something new to the oil and gas industry, since the early 1980s the industry has adopted digital technologies with the goal of improving productivity and minimizing the risk [17]. The industry had seen an exponential growth in data input volumes since 1990, increasing thus the challenges faced by decision makers. For instance, terabytes can be generated from a single drilling rig at an oilfield every day. Furthermore, up-to-date petroleum seismic data centres can contain 20 petabytes of information with ease, this is equivalent to 926 times the size of the US library of congress [18]. Even though seismic data comprises an important set of information for the oil and gas industry, other aspects of the industry generate more data than before [19]. However, much of this data sets are either unstructured or semi-structured, like e-mails, spreadsheets, word documents, images etc. and the process and management of these data can be very difficult and expensive using the traditional approach; making from the use of Big Data technology a necessity.

In spite of the technological development that occurred in the past three decades, unlike other industries, the oil and gas sector did not benefit from the derived data in a meaningful way [20], approaching them thus with the same old attitude that was used previously. Only an insignificant fraction of the data is used for decision making, leaving in the process potential valuable information that could be either thrown away or stored within a service company instead of the petroleum company that is responsible for the asset. Gllimer [21] argue most of the data gathered within the industry is going fallow, even with the remarkable increase in the available data. The author adds that the impact and power of software is still infant, as a consultant's opinion would weight it over quantified contributions from a machine.

Several applications for Big Data have emerged recently within the oil and gas industry, due to the technological development; however, their application is still considered conservative and with little impact on the industry's business model [17]. For instance, the use of sophisticated reservoir monitoring technology, which allows the optimization the field's depletion planning and minimize deep exploration drilling. Big Data is also used to set up the base of the industrial internet, with the goal of improving the quality of predictive maintenance. The use of cloud computing (CC) is another example of how Big Data technology could impact the oil and gas industry, Rands [9] argues that the fossil fuel industry would benefit greatly from cloud computing in the future, especially in terms of cost reduction. The CC technology introduces the client-server module that gives the opportunity for the industry's operators to analyse more complex information from a great amount of data with reduced operational costs, minimal non-productive time and low risk and uncertainty.

Other industries such as, healthcare, aviation, automotive, retail and finance have different approach to the Big Data revolution, they have redefined their businesses and operating models by getting brand new and valuable information obtained from using new tools to analyse large and complex data sets [16]. Surely, their business models differ vastly of that of the oil and gas industry and so is the data collected. However, there is no denying the industry's

increasing reliance on information technology and computational power, especially with the development of unconventional hydrocarbon and complex arising problems related to commercialisation and production optimisation. Feblowitz [22] explained how nowadays oil and gas companies might not regard Big Data and digital information as game changers within the industry, but they will start looking at them from a different perspective in the upcoming years.

B. Distributed Ledger Technology - Blockchain

Distributed ledger technology, which is also known as blockchain, and famous for being the architectural foundation for cryptocurrencies, such as bitcoin [23]. Blockchain is an open infrastructure with a shared data base that allows either companies or individuals to eliminate third parties' impact on transaction processes, helping thus in the reduction of transaction costs and increasing efficiency by eliminating any manual redundancies [24]. Contracts, inventories and payments are shared between the interested parties with a set of encrypted connections. The development of this blockchain technology presented the world with alternatives to traditional processes. Therefore, the technology is created to eliminate the need for a third party, such as banks, and create a perfectly secure, transparent and impeccable system that would reshape all industries.

The year 2017, witnessed the first application of blockchain solution in the oil and gas industry [25]; Natixis used the technology in the trade finance for the US crude oil transactions, where they helped in digitising them. Furthermore, two of the biggest oil and gas companies, BP and Shell, had launched a plan for an energy trading platform based on blockchain, to start its application at the end of 2018 [26]. The recent industry shift towards digitization had drawn the attention to blockchain to its executives, according to a research made by [27], 55 percent of the industry's executives support the idea that blockchain would be essential to gain competitive advantage, and 45 percent agree that it will change the industry. Yet, the number of organisations engaged in blockchain activities is very limited compared to its counterparts in the electricity sector [28], and the majority of them targets supporting activities, mainly document circulation and related contractual activities, and not primary ones, and focusing only on process optimisation. This could be because of the high entry barriers the oil and gas industry has compared to other industries.

The application of blockchain could introduce secure and relatable solution across the energy value chain. There is still little research done on blockchain technology within the oil and gas industry, but the range in which it could be applied is immense [27]. In the upstream, blockchain technology has the potential of being used in the maintenance and tracking of equipment and their operating conditions. The technology could also be used to track the wells construction and design processes; BHP Billiton is implementing a wellbore tracking application based on blockchain that would replace their current manual process that uses spreadsheets and e-mails to do so, this would eliminate any potential for human error, especially since wellbore samples are very expensive and impossible to replace [29]. At the midstream section, blockchain solutions could be used in energy trading, equipment maintenance and inspections and contract management (smart contracts); "Smart contracts" is one of the main areas blockchain can reshape the oil and gas industry [27], seeing the number and volume of contracts employed in a project within the industry, presenting thus difficulties for contractors, sub-contractors and suppliers in terms of cost tracking and inventory deployment, which is based mainly on manual processes. Smart contracts would create a simpler supply chain and an improved contractual obligation for involved parties.

With the growing interest oil and gas industry have for blockchain technology, decision makers and stakeholders will have to fully understand the technology's advantages and shortcomings in order to insure a maximum benefit. Brooks and Wiseman [30] argue that the best application of blockchain technology within the oil and gas industry would come from the combination of the blockchain features with specific shortcomings within the organisations' current state. This would help in defining the technology's limits and addressing them with either conventional or alternative technologies.

C. Smart fields

Yeten *et al* [31] defined a smart well as a nonconventional well with downhole instrumentation, that could be either sensors or valves for flow control, that are installed alongside the production tubing to monitor one or more well parameters, mainly temperature and pressure. The term evolved later on to smart field including thus other aspects of the upstream operations. The term includes the combination of people, processes and tools used for the management of data across the whole upstream section. It offers the technology to better capture much larger volumes of data with greater frequency, and the opportunity for operators to analyse the collected data in real or near-real time impacting thus the decision-making process and optimising the performance of wells, reservoirs and facilities.

Gustavo *et al* [32] explain how the introduction of sensors and data computation in the 1990s formed the cornerstone for the smart fields. A simplified setting of a smart field is as follow; the wells are first to be equipped with permanent measurement equipment and control vales to mainly help in the daily production and reservoir management. Sensors to provide geophysical reservoir imaging could be implemented to monitor the movement of fluids alongside the well and detect any significant changes within the property of the petroleum. The shift from the standard 0/1 control systems to the inflow control valves would guarantee an accurate control of all the operations at any segment of the reservoir, leading thus to smooth adjustment of operations. In the case of connection lost with the operators, the network of microprocessor-based instruments scattered all over the field would insure the operation's safety.

Smart fields' impact on the organisation can be seen on both, on the field level and management level. Onsite, the smart technology would give operators the opportunity to

have a detailed knowledge and control over operations [33]. Furthermore, it will increase their safety and reduce the workload. In terms of management, smart field technology would improve the transparency of information for managers and executives, which will have a direct impact on the organisation's daily production and help it grow its market share.
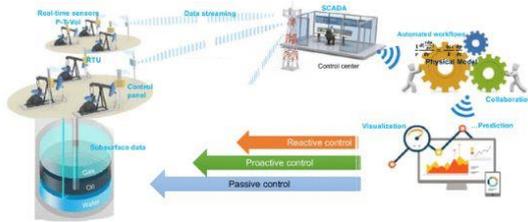

Fig. 2. Overall description of a Smart Field system [32].

In addition to operation control, the smart solutions within smart fields employ the reservoir's lifecycle modelling and optimization [31]. The lifecycle optimization is set up to overcome the traditional reactive aspect of the process control, which rely on the setting of instruments to restore operations' attributes after the emergence of problems, with a more proactive strategy that anticipates any possible changes that could impact the production and makes decision taking that into consideration [34].

The Saga Petroleum (subdivision of Statoil) introduced the first smart well in 1997 as a pilot project in the Snorre Field in the North Sea, since then the application of this smart solution had increased all over the world [35]. During the mid-2000s, Conoco Phillips started an integrated operating program within the North Sea, with a focus on optimisation of operations and data management. The program introduced a system that tracks well performance against a plan and was also equipped to control them along with the facilities [36]. The technology did not find its way to the middle east until 2010, when the Kuwait Oil Company introduced The Kuwait Intelligent Digital Field program, which was considered by a lot in the industry of being one of the most ambitious projects within the industry. It used new generation communication and sensor devices [37].

The use smart technology within oil and gas fields (wells) has proven to be very beneficial, which was documented is several studies [38]-[40], for both conventional and non-conventional (more complex) oil fields. As they have proven to be efficient in preventing water coning, improving production rates, increasing oil and gas recovery and reducing risk and expenditure.

III. CONCLUSION

In an industry operating in a volatile environment and high risk, companies should review their business models to stay competitive and meet shareholders' expectations. The oil and gas industry is transforming at a very rapid pace, and the technological development is one of the main factors responsible for this change. Smart solutions are an example of the impact of technology on the industry, they are becoming more and more present within the industry to improve its operations throughout the energy production line. A broad scope review of the available literature is presented in this paper, which allowed the presentation and revelation of some examples of the smart solutions applied within the oil and gas industry. These solutions' contributions might still be considered small in the industry, but with a great potential to improve efficiency the industry is in a dire need for. They would improve the decision-making process by minimising the real-time risk assessment and analysis and reducing the costs related to production and maintenance. Seeing the nature of the sector, where managers are considers the agents to the success or failure of any project, therefore, they are entirely responsible for the use of the suitable instrumentation, facilities, infrastructure and workforce to ensure maximum benefit from smart solutions.

A limitation of the paper is its generalised perspective. The technological details of the proposed solutions are not examined in depth. A full knowledge of these details would give a better understanding of these solutions, giving the opportunity to analyse the advantages, drawbacks and challenges associated with the utilisation of the instrumentation of smart solutions. The paper had covered the available literature on the proposed smart solution in the previous two decades. In a fast-evolving industry, the production of oil and gas would move more towards nonconventional reserves thus becoming drastically complex leading to the evolvement of accompanying technology in the future.

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