The Contribute of Digital Technologies for the Oil and Gas Industry

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1. Theme Description

The IEA estimated, in the "*Medium-Term Oil Market Report 2016*", that oil demand will increase from 94.4Mbbl/day in 2015 up to 101.6 Mbbl/day in 2021 with a mean annual growth of 1.2% dragged by Asia and Middle East.[1]However, in last ten years the cost of productions have increased by about 60%, while oil prices fell down.[2] For example, referring to OPEC oil prices decreased from 109.45 US$/bbl in 2012 to 40.68 US$/bblin 2016.[3] In this scenario digital technologies can have a pivotal role in reducing costs and risks, increase production and efficient of operations. McKinsey&Company, indeed, argued that digital technologies could reduce capital expenditures of about 20%, operating costs of 3-5% in upstream and of about 50% in downstream.[4]Moreover, digitalization could create, in the next ten years, about 1trillion dollars for the sector of which 580-600 billion for upstream, 100 billion for midstream and 260-275 billion for downstream. Furthermore, it could improve productivity by about 10 billion dollars, reduce water usage and emissions by 30 and 430 billion dollars respectively and save 170 billion dollars for customers.[5] Therefore in the following sections, the main digital technologies and the digital oilfield are described.

2. Digital Technologies

The oil and gas industry has been using digital technologies since 1960s, especially in the upstream sector, with the aim to better understanding the geology of the oilfields, increasing production and safety. Some of the principle digital technologies are listed below.

Seismic Imaging

The first advanced technology was represented by the 3D seismic imaging invented by Exxon Mobil. This technique uses sound waves to create a three-dimensional image of geologic formation sand the most common is based on narrow azimuth where one vessel towing an array of streamers and sources. However, this technology

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[1]https://www.iea.org/publications/freepublications/publication/MTOMR2016.pdf

[2] H. Hassani, *The role of innovation and technology in sustaining the petroleum and petrochemical industry*, Technological Forecasting and Social Change, 2017, 119, pp. 1-17.

[3] https://www.statista.com/statistics/262858/change-in-opec-crude-oil-prices-since-1960/

[4] https://www.mckinsey.com/industries/oil-and-gas/our-insights/the-next-frontier-for-digital-technologies-in-oil-and-gas#0

[5] http://reports.weforum.org/digital-transformation/wp-content/blogs.dir/94/mp/files/pages/files/dti-oil-and-gas-industry-white-paper.pdf

is not suitable for volcanic, salt and carbonates surfaces. Therefore, since 2000s Multi Azimuth (MAZ), Wide Azimuth (WAZ), Wide Azimuth Towed Streamers (WATS)[6,7], etc. have been used in the North Sea and the Gulf of Mexico (i.e. Shell in 2009-2010 discovered a large amount of resources, about 150 million of barrel of oil and gas, by using WAZ[8]).

Nowadays is possible to form a "4D" seismic image by repeating the 3D tests over time. In this way a "moving picture" is obtained understanding how properties changed in the existing oilfields.[9,10] Furthermore, several companies have developed algorithms that allow to create more accurate images such as Kirchhoff Migration, Wave Equation Migration, Reverse Time Migration and Full Wave field Migration. Recently, a team of the University of Calgary has experimented the use of virtual reality and advanced visualization techniques to help Canadian producers to better understand and manage the steam assisted gravity drainage (SAGD) technique.[11]For more information about 3D imaging can be consulted Brown.[12]

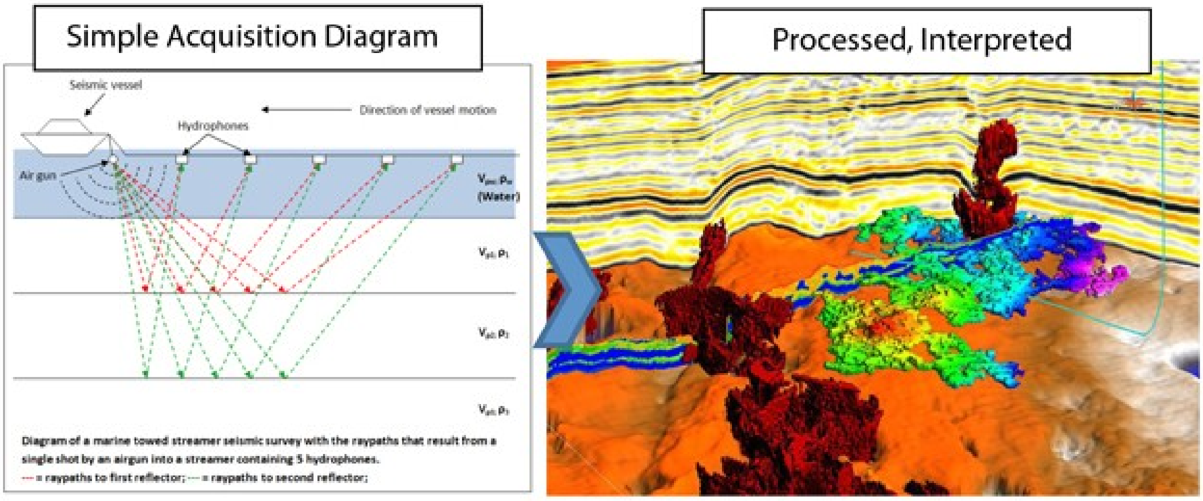

Figure 1 -On the left data acquisition by means of SCADA system; on the right 3D imaging creation.[13]

Smart Wells

"Smart or intelligent wells" are wells where sensors and valves are installed downhole.[14] Operators can control flow rates, pressure and temperature in real time and remotely without any intervention using rigs or coiled tubing. The system

[6] https://www.pgs.com/publications/feature-stories/why-more-azimuths-is-a-good-thing/
[7] A. Long, An overview of seismic azimuth for towed streamers, The Leading Edge, 2010, 29(5), pp. 512-523.
[8] https://www.shell.com/energy-and-innovation/overcoming-technology-challenges/finding-oil-and-gas/_jcr_content/par/textimage.stream/1444725407967/f916a9f8105fef5080cee8e860dcfb6e17497306f03bd155935b69e187e4be36/geophysical-imaging-brochure-2014.pdf
[9] http://corporate.exxonmobil.com/en/technology/exploration-and-production/seismic-imaging/seismic-imaging-overview?parentId=651f3f92-2d3f-42d3-9616-6f3dc5644eea
[10] http://local.esso.com/Files/PA/Europe/UK/3D_seismic.pdf
[11] https://www2.deloitte.com/insights/us/en/industry/oil-and-gas/digital-transformation-upstream-oil-and-gas.html
[12]A. R. Brown, *Interpretation of three-dimensional Seismic Data*, Seventh Edition, AAPG Memoir 42/SEG Investigation in Geophysics, No.9, 2011.
[13] http://analytics-magazine.org/how-big-data-is-changing-the-oil-a-gas-industry/
[14] http://large.stanford.edu/courses/2011/ph240/kitanidis1/

involves two types of valve: Inflow Control Valve (ICV) and Inflow Control Device (ICD). The ICVs are reactive actionable valves where the flow is inspected by adjusting the choke size position or by turning on/off the valve. Whereas the ICDs have fixed orifices and fall in the category of passive valves.[15]The first smart well application was realized by Saga Petroleum (nowadays a subdivision of Statoil) in 1997 on the Snorre Field in the North Sea. Since then, hundreds of smart wells were used in the world.[16] BP and Shell, recently, have installed smart sensors and fibre optic in the North Sea and China Sea. In the first case BP has increased the production added 10,000 bbls/d in the Thunder Horse Field, whereas Shell managed to extract oil and gas from Champion West in the South China Sea considered for 30 years a reservoir too expensive to be used.[17]

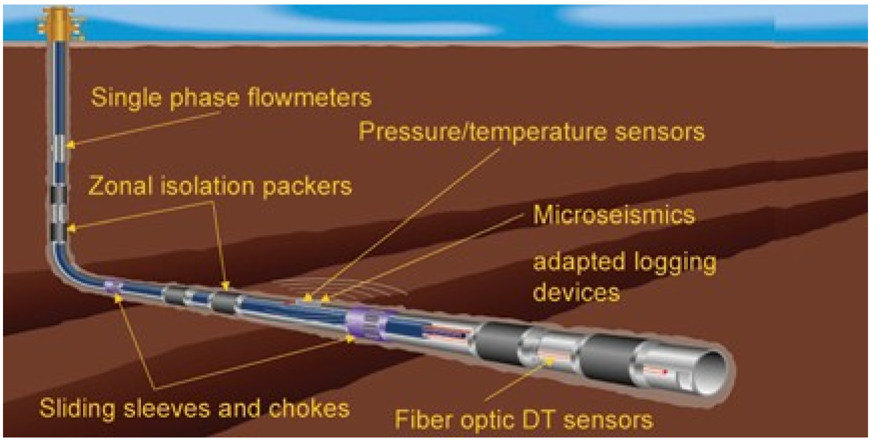

Figure 2 - Schematic Representation of a Smart Well.[18]

SCADA System

The supervisory Control and Data Acquisition (SCADA) is widespread in upstream, midstream and downstream sectors such as pipeline monitoring, process control, oil pumping regulation, etc.[19]The first SCADA system was launched on the market in 1950s by Westinghouse and North Electric Company based on telephone wires. Then the first generation was a standalone system, where the Wide Area Network (WAN) connected Remote Terminal Units (RTU), but not these to the master computer. Therefore the second generation, based on Local Area Network (LAN), allowed to create several stations where data were interchanged. However, each vendor had an own protocol and the system couldn't communicate with external device that used a different one. This led to the third generation based on an open architecture where components communicate by Ethernet connections and standards. Nowadays a SCADA system includes: RTU, PLC, Telemetry System, Data Acquisition Server,

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[15]G. Carvajal et al., I*ntelligent Digital Oil and Gas Fields Concepts, Collaboration, and Right-Time Decisions*, 1st edition, Gulf Professional Publishing 2017.

[16] https://www.sciencedirect.com/science/article/pii/S1877050917311171

[17] https://www.accenture.com/t20151218T203100__w__/nl-en/_acnmedia/PDF-2/Accenture-Digital-Oilfield-Outlook-JWN-October-2015.pdf

[18] https://www.corelab.com/promore/intelligent-wells

[19]R. L. Krutz, *Securing SCADA Systems*,Wiley Publishing, Inc., 2006.

Human Machine Interface (HMI), Historian Service and Supervisory Station. The next generation of SCADA system, instead, will be based on cloud computing.[20]

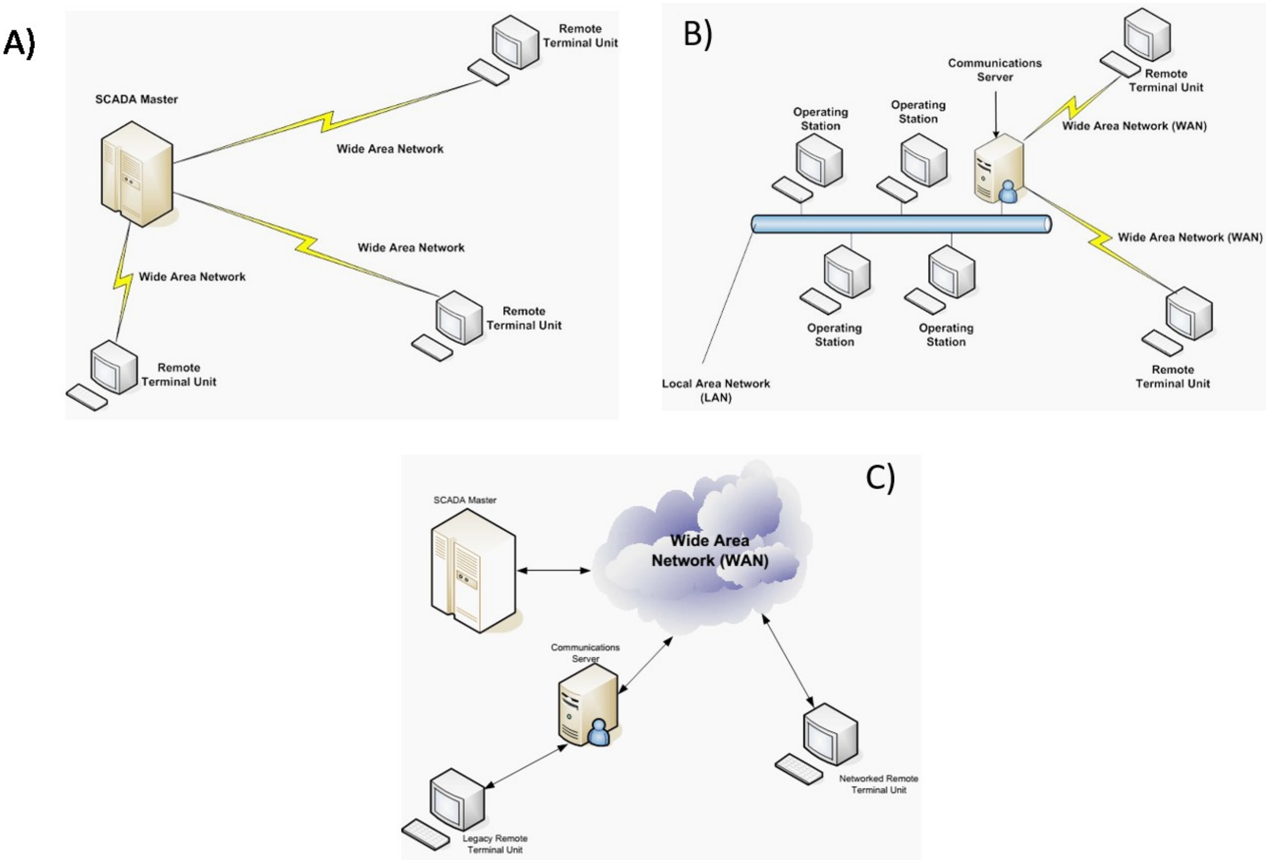

Figure 3 - Architecture of SCADA System: A) First Generation, B)Second Generation and C) Third Generation[21].

Supercomputer and Management Software

The oil and gas industry is one of the main sector that uses High Performance Computing (HPC) solutions reaching 747 million of dollars in 2012.[22] Recently, ENI has launched the HPC4 that represents the biggest supercomputer in the world overcoming BP and Total.[23] Nowadays, oil and gas companies use many software to manage supply chain (SCM) and resources (ERP). The SCM system processes data coming from ERP generating a “plan”. In this way plan is transferred back to ERP where a series of operation take place: order generation, real-time execution and reconciliation. New plans are generated whenever new data, coming from several devices, are stored in ERP system.[24]However only few SCM software can have Vehicle Routing and Scheduling (VRS) functionality. As shown inFigure 4, indeed,

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20 http://webbut.unitbv.ro/BU2015/Series%20I/2016/BULETIN%20I%20PDF/Ujvarosi_Al.pdf

21 http://electrical-engineering-portal.com/three-generations-of-scada-system-architectures#1

22 https://biztechmagazine.com/sites/default/files/document_files/148551-High-Performance-Computing-In-Oil-and-Gas.pdf

23 https://www.hpcwire.com/2018/01/23/eni-takes-lead-industrial-supercomputing/

24 L. M. Camarinha-Matos, *Collaboration in a Data-Rich World*, 18th IFIP WG 5.5 Working Conference on Virtual Enterprises, PRO-VE 2017, Vicenza, Italy, September 18-20, 2017, Proceedings.

SAP and Oracle are the main vendors of integrated software system where SCM, ERP and VRS are available.[25]

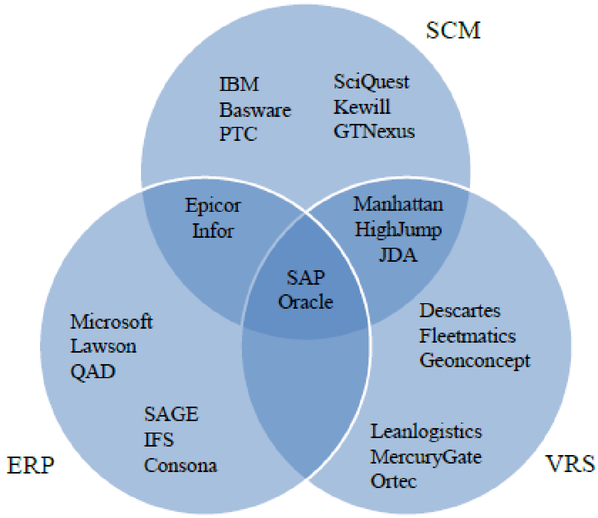

Figure 4 - Main software vendors.[25]

3. Digital Oilfield

Digital oilfield can represent the link between the digital technologies discussed above. Indeed, it consists of a distributed network of sensors, where big data analytics, mobile connectivity and artificial intelligent have a pivotal role. In particular digital oilfield allows to predict equipment failure, optimize production, "learn" and use the best practices on the field, save workers from hazardous situations etc.[17]

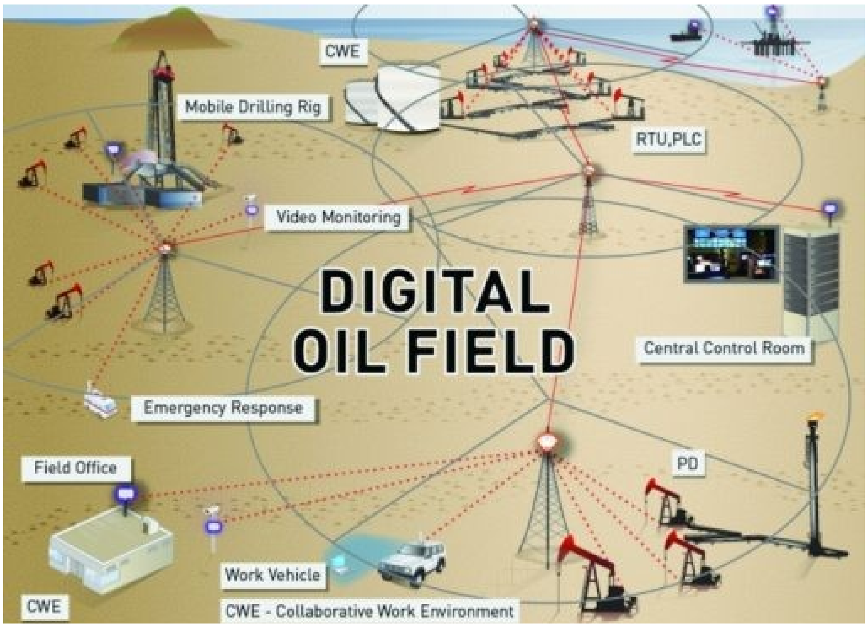

Figure 5 - Schematic representation of Digital Oilfield.

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https://www.researchgate.net/publication/319231399_Digitization_in_the_Oil_and_Gas_Industry_Challenges_and_Opportunities_for_Supply_Chain_Partners

Petrobas is a pioneer in the digital oilfield. Indeed, several pilot projects were launched in Campos Basin. The first one, dated 1994, involved Carapeba field in the Northeast area. It consisted of testing an Electrical Submerged Pump (ESP) on a vertical well (282 ft of deepness).[26] In 2006, the company decided to experience on the same basin, the integration of different intelligent technologies. Petrobas developed an integrated management centre called Gerenciamento Digital Integrado (GeDIg), by means of collaboration with technicians from Schlumberger. The GeDIg is a decision-makingcenterin which surveillance, diagnosis, planning management areas work together in the same environment.[27]This allows to take decision in real time via an interactive control screen where Key Performance Indicators (KPI's) such as downhole pressure, temperature, electrical amperage etc. can be checked and adjusted (Figure 6).Then the same procedure has been tested on different fields in Campos Basin allowing to solve problems of standardization and scalability.[28]

A) GeDIg centre room.

B) KPI's vs Operating Conditions.

Figure 6 - GeDIg and display of the parameters.[28]

Another interesting example of a company that has invested heavily in digitization is represented by Encana. This firm is a mid-size natural gas producer that operates in the USA and Canada. In 2002, Encana decided to invest into digitization to cope the volatility of gas price and to reduce cost production. In ten years the company introduced the third generation of SCADA system, spent about 20 million of dollars to develop the Production Volume Management (PVM) and 12 million of dollars in the Land and Revenue Management system. These "tools" allowed to use thin clients, web portals and to have more control to the supply chains by means of field data from drilling, production and daily reports. Two applications have also been developed called Digital Oil Platform (DOP) and Electronic Lease Purchase Report (eLPR). The first system allowed to contractor and service providers to make a digitally invoices reducing the time of payment from 60-90 days to 7 days. Whereas

[26]https://www.slb.com/~/media/Files/resources/oilfield_review/ors07/win07/intergrated.pdf
[27] https://www.researchgate.net/publication/254531042_State-ofArt_Digital_Oilfield_Implementation_in_Petrobras_Campos_Basin
[28] https://www.researchgate.net/publication/241787892_GeDIg_Carapeba_-_A_journey_from_Integrated_Intelligent_Field_Operation_to_Asset_Value_Chain_Optimization

the eLRP allowed to create a database of historical date about geological characteristics of formation and to evaluate the presence of natural gas.[29]

Recently, in 2010, Kuwait Oil Company (KOC) has launched three pilot projects called the “Kuwait Intelligent Digital Field (KwIDF)” where the principles basis of Digital Oil fields were applied. One of the main project involved Sabriyah Mauddud (SAMU) field, a carbonate reservoir in the North Kuwait. Instrumentations were upgraded with the latest pressure, temperature and flow rate sensors. The SCADA system was equipped with wireless instrumentation allowing to analyse in real time well surface and subsurface. The project involved 44 producer and 7 injector wells; by using automated workflow and collaborative decision approach the oil field recovery reached 37% in 10 wells.[30]

4. Future Trends

In the future “miniaturised” sensors could be used to increase oil recovery; automated drilling rings and robots could allow to repair subsea infrastructure and to monitor pipeline and tanks. Furthermore, drones could inspect pipelines and remote equipment difficult to reach.[31]However, the main barriers to digitization are represented by the high investment cost, cyber security and the analysis of Big Data due to their volume (petabyte), variety (structured and unstructured) and velocity (rate of generation and analysis speed).[32] In addition, a higher Return on Investment (ROI) could be achieved by reducing sensors and actuators costs and by a predictive analysis of collected data.[33]

The main area of investment and growth in the next 3-5 years are shown in Figure 7.[5]

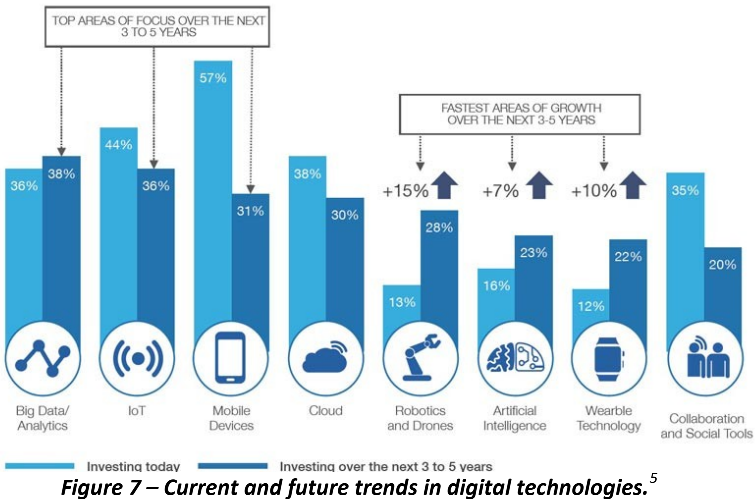

Figure 7 – Current and future trends in digital technologies.[5]

[29] https://misqe.org/ojs2/index.php/misqe/article/viewFile/397/287

[30] M. A. R. Jamal et al., *Effective well management in Sabriyah Intelligent Digital Oilfield, Society of Petroleum Engineers, 2013.*

[31] http://www.iea.org/publications/freepublications/publication/DigitalizationandEnergy3.pdf

[32] A. Gandomi, Beyond the hype: Big data concepts, methods, and analytics, International Journal of Information Management 35, 2015, pp 137-144.

[33] https://www.strategyand.pwc.com/media/file/Not-your-fathers-oil-and-gas-business.pdf

5. Conclusions

Digital technologies have been used since ‘60s in the oil and gas industry. Nowadays they include 3D/4D seismic image, virtual reality, SCADA system, supercomputers etc. Several manage software exist but only Oracle and SAP can offer integrated solutions such as SCM, ERP and VRS system. Digital Oilfield represents a link between different technologies and the projects developed by Petrobas, Encana and KOC are examples of its application. However, more efforts are necessary to better manage data coming from sensors, pipe lines, reservoir wells, due to their volume, velocity and variety. It has been estimated, indeed, that improvements in the analysis of the Big Data, could increase oil production of about 6-8%.[2] Furthermore Oxford Economics has argued that the increasing adoption of digitization could improve gains of about 816 billion of U$ dollars in global GDP by the end of 2025.[33]