Identifying Key Business Processes that Can Benefit from Industry 4.0 in the Gas Sector

Nikolaos A. Panayiotou, Vasileios P. Stavrou, Konstantinos E. Stergiou

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The Public Gas Distribution Networks Case in Greece

Nikolaos A. Panayiotou, Vasileios P. Stavrou, Konstantinos E. Stergiou

National Technical University of Athens, Zografou, Athens, 15780, Greece
panayiot@central.ntua.gr

Abstract. The Natural Gas Distribution sector is considered one of the most critical areas in which Industry 4.0 methodologies can be applied, as they form a part of critical infrastructure management where automation, information technology and high-tech solutions can offer high-level service. The paper aims to identify critical business processes that can substantially benefit from Industry 4.0 and Information Technology solutions in a Natural Gas Distribution Company which distributes Natural gas in Greece in Medium and Low Pressure.

The research conducted identified the company's business processes and highlighted these which are critical to its operation. Having identified the technological advancements in the Gas sector, the business processes that can benefit from Industry 4.0 and Information and Communication Technologies were recognized.

The results revealed three critical business processes that can be radically improved: management of new customers' connections, project management of works projects and network maintenance. Technological approaches that can transform these processes were identified to be a real-time collaborative CRM system, a real-time collaborative project management system integrated with an appropriate document management system, smart meters, sensors and actuators for real-time monitoring of important operational variables and a monitoring system which collects and generates consolidated information in a Control Room.

Identification of the processes into which Industry 4.0 and information technologies can lead to the introduction of corresponding solutions, can increase operational efficiency of company's network and minimise running costs. The research effort should be continued in order to achieve higher integration between business processes, Industry 4.0 concepts and Information Systems.

Keywords: Industry 4.0, Key Business Processes, Utilities, Gas Sector, Maintenance.

1 Main Characteristics of Industry 4.0 Integration in a Utility Company Business Processes

Industry 4.0 defines a methodology in order to transform machine dominant manufacturing to digital manufacturing (Oztemel and Gursev, 2019). Its products or services are considered the results of deep integration between industrialization and informatization (Gilchrist, 2016). The concept was introduced in Germany in 2011 (Xu et al., 2018) making up an innovative effort by the German government in order to gain a strategic competitive advantage over their key industrial competitors. In the utilities sector, Industry 4.0 can find a number of discrete applications.

In the context of Industry 4.0, utility companies are trying to implement a number of innovative solutions, incorporating Information and Communication Technologies (ICTs), Cyberphysical Systems (CPS) and Internet of Things. In this way, they are able to monitor and control their processes in a more efficient, flexible, reliable, sustainable, decentralized, secure and economic manner, using a number of suitable tools (Faheem et al., 2018). In this context, a new concept, Oil and Gas 4.0 has also been put on the agenda as an instantiation of Industry 4.0. Oil and Gas 4.0 has the potential to completely change oil and gas industry, accelerating, digitalizing and reengineering its processes (Lu et al., 2019). This concept has gained ground in recent years among businesses in the industry.

2 Main Concepts and Tools Used in Oil and Gas 4.0

Oil and Gas 4.0 in oil and gas companies is implemented with the aid of several methods and tools. Although certain techniques can be identified in oil and gas upstream sector (smart oilfield) and others can be found in the last steps of the supply chain (sales), many of the most important applications arise mainly in the midstream (intelligent pipeline, equipment maintenance, smart metering), in which special emphasis will be given in this article.

First of all, oil and gas pipelines and networks are usually centrally managed by a control room using computer-aided control, monitoring systems, sensors and actuators. In recent years, the control room's communication with pipeline points of interest (equipment, sensors and end-users) has been upgraded with more modern tools (pipeline surveillance software). In order to implement this communication, different wired and wireless communication technologies are used (Faheem et al., 2018).

Currently, most of the smart pipelines critical applications are relying on wired networks, using optical fiber technologies. On the other side, microwaves technology provides secure and high-speed wireless connection for sending and receiving a huge amount of information. In addition, wireless solutions are preferred due to higher data rates, while satellite communication is preferred due to extremely long-distance coverage (Lu et al., 2019). Sensors and actuators are located at specific preselected points

of the oil or gas smart pipeline. Specific sensors are positioned along the smart pipeline in order to detect malfunctions and activate respective maintenance mechanisms. In addition, sensors can also detect leakage in specific areas of the network and supply interruption can be ordered. Finally, advanced sensors can collect weather data, helping operators to implement actions and handling risks (Qarabash et al., 2020).

A key element of Oil and Gas 4.0 is the use of smart meters. Smart metering enables the remote control, in order to accurately measuring consumption and fuel flow at precise time windows, extracting consumption statistics, while avoiding leakage or fraud. In addition, demand-side management is generally considered a critical parameter, as changes in consumption are usually managed by altering the loads on the distribution grid (Lu et al., 2019). As regards Oil and Gas 4.0 under the prism of maintenance of intelligent pipeline, sensors and actuators are considered key parameters. By building digital twins of equipment, oil and gas companies can detect early signs of failure in advance, enabling them to take maintenance measures ahead of time, which allows them to save costs, given the fact that repair after failure is always more expensive than maintenance in advance.

Creation of digital files containing materials, consumables and equipment matrices (catalogs of equipment needed to be changed, maintained, upgraded) are also considered main aims in Oil and Gas 4.0, based on principles of automation and digitization. In addition, security plays a vital role in order to ensure stability and avoiding unwanted situations. A large amount of raw data from heterogeneous devices may contain a variety of vulnerabilities, allowing attackers to enter to the system and manipulate metering data, cause data management chaos or destabilizing oil and gas networks (Faheem et al., 2018). Based on the above, it is easily understood that the use and management of big data in an IoT environment is a matter of major importance for Oil and Gas industry.

Additional techniques can also be identified in the literature, as they are used in Oil and Gas 4.0 context. For example, the use of Augmented Reality (AR) technology in the training of operators can guide experts before the actual maintenance operation, reducing the probability of operational errors, while blockchain technology can be used in order to secure data, increase transparency, and provide tracking for goods. (Lu et al., 2019).

The use of ICT Information Systems in collaboration with industrial automations and cyberphysical systems (CPS) in Oil and Gas 4.0 aims mainly to enhance smart pipelines efficiency and reliability. At first, customer relationship management tools (CRM) are used closely associated with smart pipelines in order to secure better communication with customers and subcontractors (Panayiotou et al., 2019 [a]). In terms of in-company communication, modern ERP's and Document Management Systems can help companies, with the aim of document controlling. ICT implementation in Oil and Gas industry can provide user-friendly services to customers, bringing economic benefits to both sides. In addition, information systems aim to operate in

conjunction with industry partners in a single framework in order to optimize business processes, customer service and cost savings (Merlin, 2010)

Business process collaboration with Industry 4.0 (and Oil and Gas 4.0) is accomplished using Process Modeling and similar methods, providing stakeholders with adequate means in order to control processes efficiently and effectively (Rehse et al., 2018). Under the Industry 4.0 concept, systematic attempts have been made in order to adopt industrial digitization and transformation under a single architecture. For example, Panayiotou et al. (2019[b]) established an Industry 4.0 architecture in order to integrate business automations, information systems, business processes and the physical world.

In the following paragraphs, a case of a Natural Gas Distribution company is presented and the approach it followed for the introduction of Oil and Gas 4.0 technologies driven by its business processes specific needs. Although Natural Gas as a product can be classified as "non-intelligent" as it cannot add embedded information or connectivity to it, Natural Gas Distribution companies place particular emphasis on Oil and Gas 4.0 concept, as smart pipelines, maintenance and metering are their main area of activity. In this context, Oil and Gas 4.0 is widely applied to Natural Gas Distribution companies, and its relation with business processes will be demonstrated in the following case study.

3 The Case of a Natural Gas Distribution Company

During the implementation and integration of Industry 4.0 in a natural gas distribution company, the design and modeling of business processes is of particular value. Without proper planning of company’s business processes, it is not easy to identify the fields in which Oil and Gas 4.0 can be implemented. The current effort aims to implement certain Oil and Gas 4.0 tools and techniques in a natural gas company operating in Greece (DEDA S.A.). DEDA (Public Gas Distribution Networks) SA is a newly established company, founded in 2017 having as its main activity to operate as the Distribution Network Administrator (in Medium and Low Pressure) for Natural Gas in Greek Territory (with the exception of Attica, Thessaloniki and Thessaly regions). In particular, the company's core business includes planning, study, development, maintenance, operation and management of the natural gas distribution network in the abovementioned geographic areas. Monitoring of the whole distribution process is one of its key responsibilities, in addition to the measurement of natural gas quantities delivered at delivery points. In addition, maintenance and upgrading of the distribution network remains a major priority, as DEDA’s network is designed not only to support the transfer of natural gas from high-pressure network, but also to ensure the safe distribution from medium and low pressure network to the final consumers. DEDA is aiming to develop a network of above 1,200 km in the next few years.

During the case study, the company's business processes were initially identified and grouped into distinct groups, with the help of the company's staff, while a Value Added Chain Diagram was created. A total of 10 personal and group interviews took place involving 12 DEDA employees (senior executives and company officers). Subsequently, a literature review was implemented in order to record existing technologies which could help the company to transform its processes. As a final step, an effort was made in order to identify business processes in which the abovementioned techniques could be applied, while a detailed study was implemented in order to plan the future situation (TO BE) of these processes and the way they could be improved using Oil and Gas 4.0 technologies. The research question can be stated as follows:

- In which business processes of a natural gas distribution company can Industry 4.0 be implemented, and which tools or techniques can be exactly applied?

The VACD diagram which resulted is depicted in Figure 1. In conclusion, 93 processes have been recorded, divided into 7 process groups. As regards the literature review, regarding Oil and Gas 4.0 technologies, results are summarized in the second part of this article. Concerning the identification of processes in which Oil and Gas 4.0 could be used, a total of 38 processes were found in which such technologies could be used in an integrated way (indicated with an asterisk in Figure 1).

Regarding **client's management** of the company, as a complex process with many stakeholders, requires a huge workload and its automation will save a lot of resources which could be allocated to other tasks. It will also reduce the mistakes on the part of the company. Concerning this process, a new CRM software, which is about to be installed, will handle new connection requests, in order to be completed smoothly. The same system will handle customer complaints, in order to have a unified view of the customer's behavior during their lifecycle. Concerning the **Financial Management**, which is critical for the overall operation of the company and has increased oversight needs, invoices will be managed through an integrated system with full visibility of the end-to-end "sell to collect" process group, while employees will have the ability to monitor invoices throughout their life cycle.

In addition, **Project and Network Management** is considered a critical area in the natural gas network operation, for a company such as DEDA that aims to expand its network in the coming years and serve a larger amount of clients. For that reason, a number of procedures related to the development of the company's network are going to be reengineered (project bidding, monitoring of the contract and monitoring of the financial part of the project, monitoring of DEDA and subcontractor's performance, delivery of materials, project completion) using a Project Management System supported by a Document and Workflow Management system.

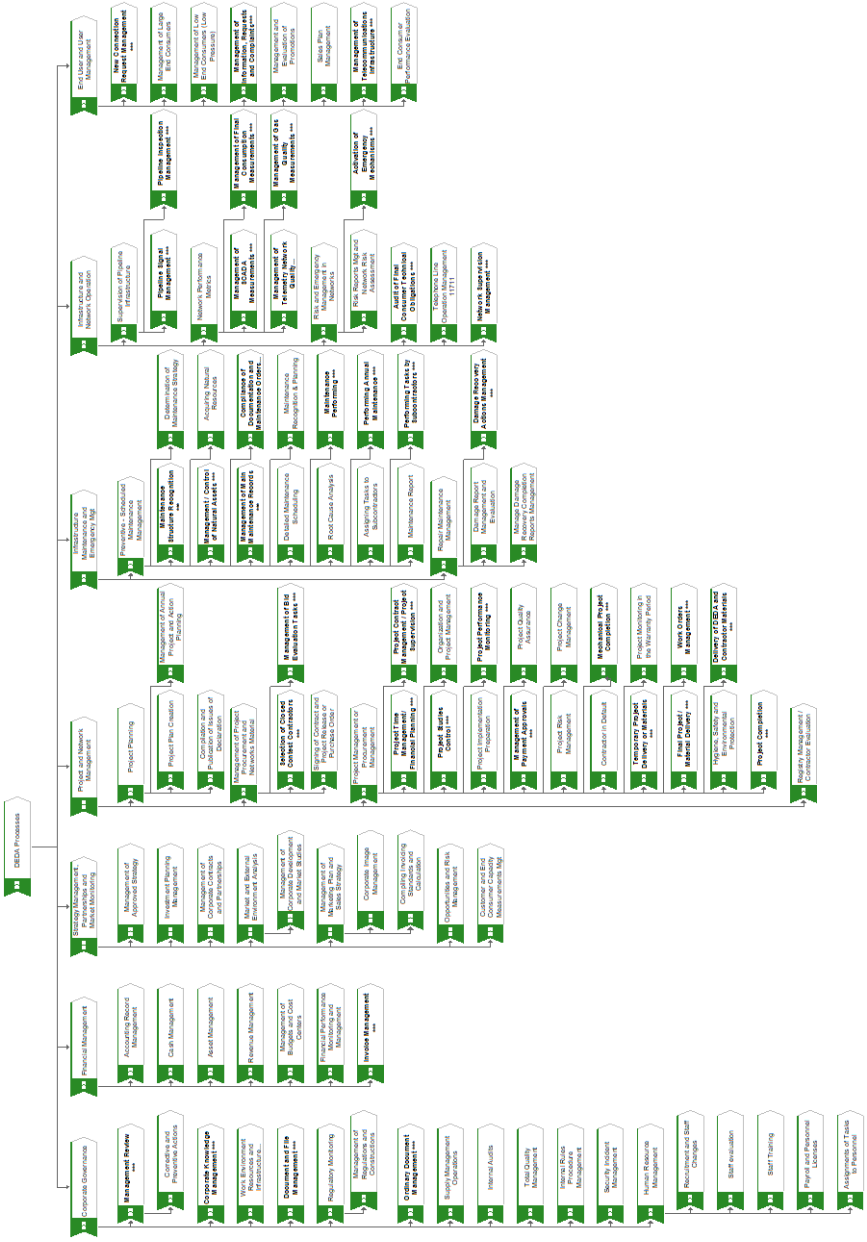

Fig. 1. DEDA Value Added Chain Diagram (the selected processes are indicated with an asterisk)

Based on the current processes, **network maintenance** takes place either in a preventive or in a corrective method. In the near future, based on the new Oil and Gas 4.0-based techniques (implementation of a control room, in which all information

from the pipelines and end users will be directed using appropriate sensors, actuators and smart meters, through the operation of a parallel data network), real time network status and malfunctions will be detected. In case of emergency, a vehicle (terrestrial or UAV) may be sent and transmit image by satellite from the damage area so that appropriate personnel and equipment can be dispatched. All of the aforementioned procedures may be carried out in collaboration with subcontractors who undertake part of the network maintenance. All data are recorded in a network surveillance information system implemented in the control room.

Concerning the **network operation** processes which involve Industry 4.0 techniques, the company has to take a series of measurements at various points of the pipeline. All of these metrics will be monitored by the control room. Real-time monitoring of the pipeline status (using sensors) will also be performed. Finally, the company is obliged to regularly check the facilities of gas consumers using specialized equipment, while the results have to be sent to DEDA's control room.

Finally, in the **Corporate Governance** processes group, three processes could be supported by an appropriately designed Document and Workflow Management system (Management Review, Corporate Knowledge Management, Document and File Management). Especially the Management Review process was completely reorganized in order that all stakeholders have the ability to monitor process real time metrics. It should be emphasized that the technologies which have been prioritized at this stage are not the only Oil and Gas 4.0 technologies which can be applied in a gas distribution company, and possibly the next implementation step in DEDA's case is to adopt some of the technologies which have not been adopted in this step of the company modernization.

4 Conclusions

It became evident that Industry 4.0 in combination with the cooperating Information Technology solutions are issues of primary importance for the gas sector in general and for gas distribution companies in particular. Maintenance and operations management, project management, as well as day-to-day customer management are important activity areas, interconnected around the Factory of the Future concept.

While the identification of critical business processes is considered the first major step, the contribution of Industry 4.0 in processes such as network maintenance and invoicing became immediately evident in the analysis. However, it was also clear that the introduction of supportive information systems (a collaborative CRM and a Project Management System supported by a Document and Workflow Management system) were additionally needed in order to achieve fully streamlined and integrated business processes. CRM proved to play a key role regarding the communication of the company with other stakeholders, while the Project Management software facilitates the monitoring of works and maintenance projects. These two software solutions

are fully integrated with the Industry 4.0 solutions for gas metering and real time monitoring of the gas network operation that provides all the necessary data in a Control Room in order to be transformed to information and decisions.

The gas distribution companies are expected to benefit from the introduction of Industry 4.0 solutions and Information Technology. However, in order for the necessary investment to really pay-off, the selection of the technological solutions must be driven by business processes needs. In the future, emphasis should be placed on designing business processes taking into account all actors involved. In addition, the impact of the implementation of the abovementioned technologies should be assessed in order to aid decision makers in their decision regarding their final adoption.

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References

1. Faheem, M., Shah, S.B.H., Butt, R.A., Raza, B., Anwar, M., Ashraf, M.W., Ngadi, M.A, Gungor, V.C.: Smart grid communication and information technologies in the perspective of Industry 4.0: Opportunities and challenges. Computer Science Review, 30, 1-30 (2018)
2. Fang, X., Misra, S., Xue, G., Yang, D.: Smart Grid –The New and Improved Power Grid:A Survey. IEEE Community Survey Tutorials, 14, 944–80 (2012)
3. Gilchrist, A., 2016. Industry 4.0: The Industrial Internet of Things, Apress.
4. Lu, H., Guo, L., Kun, M.: Oil and Gas 4.0 era: A systematic review and outlook. Computers in Industry, 111, 68-90 (2019)
5. Merlin S.: Smart utilities and CRM: The next phase of customer management in utilities. Journal of Database Marketing & Customer Strategy Management, 17, (2010)
6. Oztemel, E. and Gursev, S.: Literature Review of Industry 4.0 and Related Technologies, Journal of Intelligent Manufacturing (2018).
7. Panayiotou, N., Stavrou, V., Stergiou, K.: Reengineering of the New Customer Gas Connection Process Utilizing Industry 4.0 Technologies, The Greek Case of Public Gas Distribution Networks S.A., ISCSIC 2019, September 25–27, 2019, Amsterdam, Netherlands (2019) [a].
8. Panayiotou, N., Stergiou, K., Stavrou, V.: The Role of Business Process Modeling & Management in the Industry 4.0 Framework, INAIT 2019 – Industry 4.0 and Artificial Intelligence Technologies, Cambridge, UK, August 19 – 20 (2019)[b].
9. Qarabash, N., Sabah, S., Qarabash, H.: Smart grid in the context of industry 4.0: an overview of communications technologies and challenges. Indonesian Journal of Electrical Engineering and Computer Science. 18 (2), 656-665 (2020)
10. Rehse, J.-R., Dadashnia, S. and Fettke, P.: Business process management for Industry 4.0 – Three application cases in the DFKI-Smart-Lego-Factory. It - Information Technology 60(3), 133–141 (2018).
11. Xu, L.D., Xu, E.L. and Li, L.: Industry 4.0: state of the art and future trends. International Journal of Production Research, 56(8), 2941-2962 (2018).