Life cycle management of an integrated operation solution for the LNG supply chain

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Adaptation of new technologies creates new business opportunities. This paper focuses on life cycle management of an integrated operation solution. The solution is based on adapted both already established process automation technologies, as well as modern internet-based technologies. The industrial case study is related to adapting an existing solution to developing LNG market in order to generate new growth opportunities.

1. Introduction

This research paper focuses on solution development in an industrial environment. The motivation behind this paper is that growth of service business provides a tangible alternative to grow business in a traditionally product based business (Kowalcowski et al., 2017). The primary focus in this paper is on lifecycle management of an integrated operation solution. However, let us start with the technological background of the solution. Distributed Control systems (DCS) was developed in 1970s for process control purposes to different type of processes in different industries. Afterwards, the technology development related to DCS has been in a phase of incremental improvement without any drastically new technology refreshment. Also, the system structure is very much the same today as in the beginning. The technology structure is based on the input-output (I/O) to connect analog signals of the sensors and the actuators to digital system and lately different fieldbus technologies like Profibus and Fieldbus foundation are more and more used and it has replaced to some extent traditional I/O to network solution. Process control is implemented in controllers and workstations are used to Human-Machine-Interface (HMI) and to engineering.

The DCS market follows very much the corresponding industry trends. Therefore, overall DCS market development has been very modest in last years. Especially power industry has been declining due to increasing use of the renewable energy, which doesn’t use DCS and oil and gas has been also declining due to declining oil price in last years but lately it has started to increase. Power industry and oil & gas represent a major part of the overall DCS market and therefore DCS market development has been very modest and even declining in last years. (O’Brien, 2016, p. 7)
DCS vendors are trying to expand their offering by creating new functionalities to industry verticals and bundling their offering to serve selected industry segment. A typical area to expand functionalities is Production Management and bundled functionalities including process control and Production Management is called Collaborative Production Management (CPM). (O’Brien, 2016, p. 9)

2. Research objective

When DCS vendors expand their offering to CPM solution for a new industry utilizing IoT technology they typically face challenges due to a new type of technology and the new industry requirements. The objective of this paper is to introduce a framework for the life cycle management of a CPM solution. The life cycle of CPM solution comprises of the solution development, the operation use, and the solution phase out. This paper focuses on the first two phases: 1) the solution development and 2) the operational use. The framework will pay a special attention to taking into account the new industry requirements in the solution development and on the other side the role of different parties in operational use.

The following research questions can be formulated

- How can the new industry requirements be taken into account in the CPM solution development
- How can the life cycle of CPM solution be managed to utilize IoT technology by DCS vendor

All this should be done in order to manage identified challenges properly.

3. The framework for the life cycle management

The service business revenue has a significant role in the DCS vendors’ business and it means mainly upgrades of systems, service contracts and a small extensions with existing customers. All in all the service business is important to manufacturing companies (Baines et al., 2017).

When DCS vendors develop CPM systems they face new types of challenges due to the nature of used technology. CPM systems aim to improve productivity in a production plant or a supply chain. In order to improve productivity, the CPM system needs to collect data, create information, and finally manage and optimize the operation as described in Figure 1. The connection to the production process and data collection are the standard features of a DCS system but the connection to data sources like e.g. mobile devices used by the logistic companies requires the new type of technology, which is not traditionally used in the DCS systems. Another area of the new technology is data handling and computing in a cloud environment. The life cycle management of this new type of technology requires a new approach compared to a traditional DCS system.
The DCS vendors face also challenges to use data to optimize the production plant or the supply chain. This requires specific knowledge of the business process which the CPM system aims to optimize. The best level of required knowledge for the business process is behind the owner of the business process. This knowledge is very crucial in the optimization in order to improve the productivity of their operations.

### 3.1. The CPM solution development

As mentioned above the development of the CPM functionalities requires a detailed knowledge of the business process. This special knowledge needs to transfer to functionalities of the CPM system which operates and optimizes the production plant or the supply chain. So the process to develop the CPM system consists of two totally different competences: 1) business process related competence and 2) IoT technology related competence. These competences have to be managed properly during the development phase. For this purpose, the four phase model is described in the Figure 2.
Fig. 2: The Framework of CPM solution development (Gilchrist, 2016)

The first phase is the business process requirements. The CPM system aims to improve a certain business process and it needs to be in line with company’s strategy. Naturally, the owner in this phase is the business owner who is a decision maker and an improved business process would help him to reach his targets.

The second phase is related to user requirements. This means how to implement the new improved business process from a user’s point of view. Typically, for example, the productivity is improved by changing faster to a new product in the manufacturing process, avoid some work, make parallel two work processes, which were in row before etc. The user requirements make solid basis for new functionalities in the next phase. Owner for this phase is an operation manager. However, this phase is important to do in co-operation with an IoT technology expert to ensure realistic implementation of the improved business process.

The third phase is the function definition. This means a detailed specification for the functionalities of the improved business process. It is important to emphasize that the specification needs to be detailed enough from the technical point of view. However, this phase requires also good co-operation between operational staff and the IoT technology expert. The functionalities of the system can be divided as presented in Figure 3 (Gilchrist, 2016). Naturally, the role of the different domain can vary in the different application. For example in a CPM system, the key area is operations domain.

The fourth phase is the implementation where the functions defined above are implemented in the real environment. IoT technology knowledge is crucial in successful implementation and the platform builder is responsible for this phase. But the knowledge needed for implementation is very much different than traditional know-how of DCS.
3.2. The operational use of CPM system

As mentioned above, the IoT technology requires a new approach for the life cycle management. The DCS system is normally managed during the operational use phase by DCS vendors’ customer, which is called an end user and the DCS vendor supports the end user. The amount of the support depends on the knowledge and available resources in the end user’s side. Nevertheless, in case starting to use IoT technology the end user’s capability to manage the entity is rather limited. On the other side, the CPM solution is naturally platform used by many end users so it makes a lot of sense to take a full responsibility of IoT technology by the DCS vendor and the end user only uses the functionalities of CPM system. Additionally, there may be several users around the same business process for the CPM system and this is the case at least in the supply chain optimization and all these users have different roles in the business process. The DCS vendor can then manage the CPM system completely, and end users and other users are only using functionalities. This type of model is typical SaaS (Software as a Services) where software, CPM functionalities, are sold as services to an end user. In this model, the whole management of the IoT technology is outsourced from the end user to DCS vendor. This model is presented in the Figure 3.

IoT technology is developing very fast and the system requires continuous updates to ensure the correct functionalities and naturally end users have limited skills to take this responsibility. One important question is the data storage. There are very sensitive operational data in this system and many end users are skeptical to store that data in the cloud-based storage services. Therefore the preferred model is to store operational data to customer’s server. But on the other side, the CPM system software is in the DCS vendor’s cloud from where it is provided as SaaS to end users and their partners around the same business process.
4. Industrial internet based solutions for small-scale LNG market

Industrial internet provides viable opportunities for various industries. One major area showing potential is to re-engineer value chains and create new business models (Lee et al., 2015). Industry 4.0 is expected to improve the competitiveness of industrial production in Europe (European Parliament 2016). Actually, it is a policy framework defining and describing how to adopt new technologies in manufacturing (Drath and Horch, 2014). Industry 4.0 is about increasing productivity and competitiveness both in manufacturing and in a related supply chain. The main increase in productivity takes place while increasing the efficiency and speed of processes within a company or a value network. Large amounts of accumulated and real-time data can be applied to in life cycle management of an integration operation solution.

New ICT-related technologies make Industry 4.0 development possible and give opportunities to improve activities. Industry 4.0 describes how machines and other technologies adapted in manufacturing communicate with each other. In order to take this into a reality Internet of Things (IoT) is one of the core technologies for Industry 4.0. Communication between networked machines and physical objects is a major issue. This is expected to allow a decentralized production and adaptation on potential changes in demand. The changes created by Industry 4.0 are not only technological but also organizational (Lasi et al., 2014). These organizational changes are not necessarily inter-organizational, but rather they exceed over organizational boundaries within the value chain.

There is a diversity of approaches and business models on LNG markets. However, potential opportunities in markets should be seized proactively (Hemmingsen – Reddy, 2017). There is a need to rethink business and operating models to capture value. Biscardini et al. (2017) encourage to consider also small-scale LNG marketplace and seize its growth opportunities. The DCS vendors are already evaluating the possibilities to utilize IoT technology in the DCS functionalities. However, there are many limitations as e.g. the real-time controls for the critical processes, fast response times and high availability requirements. Nevertheless, there are areas where these requirements are not so critical and they are natural first real cases to utilize IoT technology. One of this type of area is supply chain through several logistic parties where the overall logistic process can be optimized significantly using continuously updated data from several different sources (O’Brien, 2016, p. 10).

KPMG (2017) argues that there is a major potential to increase liquefaction capacity in the near future. This means that there will also need to transfer this production to end users. The use of liquid natural gas (LNG) has been increasing lately for the industrial use and especially the transportation of LNG has been growing. The main reason behind this development has been stricter environmental requirements like lowering the sulfur emission limit in the marine industry. This requires new infrastructure to LNG distribution from the liquefaction plants to fueling stations. Therefore, the
LNG distribution market is one of the few growing markets providing a good opportunity automation vendor to grow their business. The firms operating on LNG ecosystem should operate with an increased customer orientation. This has also an effect on what kind of services in the ecosystem will be offered. (KPMG, 2017). A major issue in a more customer-oriented operations is the reliability of the LNG supply. In order to anchor major customer organizations it is important to understand customer organization’s business strategies and align operations and technological solutions to support them. These are among methods to absorb customer knowledge (Storey – Larbig, 2017). This is a crucial element while intending to secure anchor customers on a growing market.

5. Industrial case study on Valmet DNA Integrated Operation

Valmet is a major Finnish technology company offering DCS. Their solution is called Valmet DNA and it is mainly intended for pulp&paper and power industries. Valmet provides also their system to other industries but they are a minor part of Valmet’s business. Valmet aims to expand to the new market like LNG distribution by developing integrated operation solution to manage LNG supply chain.

Valmet has expanded their offering to the new industry vertical LNG supply chain by developing a CPM system on the top of their DCS system. The new system is called Valmet DNA Integrated Operation and it collects operational data from a complete LNG supply chain and store all data to a server owned by an operator. Data is updated continuously on-line using sensors and data from the mobile device, which are used by logistics companies in trucks and ships. Continuously updated data is used to manage a complete LNG supply chain.

5.1. Valmet DNA Integrated Operation solution development

Valmet DNA Integrated Operation was developed in a good co-operation with an LNG operator, and four different phases presented in Chapter 4.2 can be recognized in the development phase.

5.1.1. The business requirements

The business requirement is to improve efficiency in the small-scale LNG supply chain. LNG supply chain starts from the liquefaction plant from where the LNG is transported to terminals by ships. Terminals are like intermediate storage for the LNG and from where the LNG is typically transported to end users by trucks. LNG transport is often done by external transport companies but of course, some LNG operators may even have their own ships for LNG transportation. The CPM system aims to improve efficiency in the business process related to LNG distribution.

5.1.2. The user requirements

User requirements are related to the planning of LNG transport and follow-up of real transport as presented in Figure 4. User requirements are very much connected to
traditional ERP (Enterprise Resource Planning) system which is partly moved to the CPM system - Valmet DNA Integrated Operation. One of this type of functionality is a sales forecast, which is the basis for transport planning. LNG operator makes a transfer plan, which means the amount of LNG (Tons, MWh) which will be transported from one location to other location. The transfer plan is given to a logistics company and it is a binding order for this specific transport. Then a logistics company is making a detailed route plan in order to fulfill transfer plan in practice. The real transport is followed automatically by Valmet DNA Integrated Operation. It is worth to mention that all communication between different parties is done by using mobile devices and all documentation are done automatically by Valmet DNA Integrated Operation. Traditional model to make this logistic operation required a huge amount of communication trough phone, emails and so on. Now Valmet DNA Integrated Operation is streamlining and automating the whole communication process.

![Example of transport and communication](image)

**Fig. 4:** The LNG transport process from the user point of view

### 5.1.3. Function definition

The control domain is done close to physical processes by using a DCS system like Valmet DNA, where on-line controls of the real process are implemented. This is out of the scope of Valmet DNA Integrated Operation, but the data is gathered from this level.

The collected raw data from the control domain is used to create information like e.g. the amount of LNG energy in MWh in different terminals as well as different quality parameters. This information is very important to an LNG operator and also some information is shared with involved logistic companies. One example of sharing the information through a mobile device is presented in Figure 5.
The operation domain is the key to manage the LNG transport and planning phase consisting of two parts: transfer plan and route plan. Transfer plan is done by LNG operator and it can cover a certain period of time for LNG transfer. For a ship operator it may be only one ship delivery, but for truck operator it typically includes several individual deliveries. The route plan is done by a logistic company and a sample display to make a route plan is presented in Figure 6. Then all loading and unloading data like weigh in, weigh out, tons, MWh are measured and stored automatically. This information is shared with logistic companies and they are making invoices based on this data.

Application domain means the (Amazon Web Services) AWS environment where the applications are implemented. Then applications are used to make energy calculations, balance reports, and quality reports while the information is shared through mobile device to users.

5.1.4. Implementation

The basic architecture for implementation is presented in Figure 7. Proximity network consists of DCS systems on customer’s sites and from there the data is collected to LNG operator’s server which is called metering station. The core of an application is AWS system, the communication is done to user interface (UI) by using API REST request, and the HTTPS requests are used to connect AWS to LNG operator ERP system. This implementation makes it possible to provide Valmet DNA Integrated Operation functionalities to LNG operator with SaaS model. On the other side, the critical information is stored by LNG operator server based on their requirement.
Fig. 6: The example of rote plan in Valmet DNA Integrated Operation

Fig. 7: The basic architecture for implementation of Valmet DNA Integrated Operation
5.2. The operational use of Valmet DNA Integrated Operation

Valmet is managing the platform Valmet DNA Integrated Operation and they provide functionalities to other parties by using SaaS model. The roles of the different parties in the operational phase are presented in Figure 8. Due to the fast development of IoT technology, the software needs to be updated quite frequently. Another important area is to develop functionalities further according to LNG operator’s interests. There are many possibilities to optimize different processes, that can be done using the platform Valmet DNA Integrated Operation.

LNG operator has an administrative role to manage daily operation and they define the roles of different logistics companies. Actually, Valmet DNA Integrated Operation is their tool to run LNG transport and ensure timely deliveries to end customers. The crucial information related to an operation is stored by LNG operator’s server and they are responsible for maintenance of this part of the system.

Logistic companies are using Valmet DNA Integrated Operation and their access to a system is managed by the LNG operator. Their access typically means route planning, loading, and unloading functionalities. They will also receive the accurate information transferred LNG for invoicing purposes.

The final LNG users are not yet very much connected to a system, but this is under further development. A natural role of LNG users is to inform automatically the amount of LNG to Valmet DNA Integrated Operation to make it possible to trigger automatically LNG transfer when it is needed.

Fig. 8: The role of parties in CPM operational use phase
6. Discussion and conclusions

The first research question was how can the new industry requirements be taken into account in the CPM solution development especially from the DCS vendor's point of view. In this paper, the four phase model was presented to manage the CPM solution development. The new approach is crucial because the CPM system consists of two totally different competences: 1) business process related competence and 2) IoT technology related competence. These competences have to be managed properly during the development phase. The new model is applied to develop Valmet DNA Integrated Operation which optimize the logistics of LNG distribution.

The second research question was how the life cycle of CPM solution can be managed utilizing IoT technology by DCS vendor. This is a very crucial issue due to the new type of technology. Therefore the new life-cycle model was presented in order to take into account the above-mentioned challenge. The model is focusing on two parts: 1) product development and 2) operational use and the model was applied to Valmet DNA Integrated Operation.

Industry 4.0 is expected to improve the competitiveness of industrial production in Europe (European Parliament 2016). The Valmet DNA Integrated Operation is a good example of re-engineering value chains with the help of new technology in order to increase productivity and competitiveness in LNG distribution according to Industry 4.0. The system is currently in pilot use and first results are promising. This also creates a good opportunity to Valmet to penetrate a new market-place.

LNG industry, just like many other dynamic industries is continuously evolving. This is an issue that should be taken into account in the CPM solution further development. The topic requiring more research is how LNG distribution efficiency can be further improved by utilizing data visualization and machine learning which are possible on the top of developed CPM system. The experiences in the area of data visualization and machine learning from other industrial areas can be adapted also to new industries. However, the characteristics and potential limitations of the new industry should be carefully considered.

Another interesting research topic in the future will be the role of ERP and CPM system because some functionalities traditionally implemented in ERP system were moved to CPM system – Valmet DNA Integrated Operation. This may have the big impact on the different type of companies business on this market.

List of references


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