A METHODOLOGY FOR SYSTEM ARCHITECTING OF OFFSHORE OIL PRODUCTION SYSTEMS

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1 INTRODUCTION

Complex systems need an exhaustive analysis at the preliminary design stage in order to maximize the economic results of the investment. This applies in particular to the design of oil and gas production platforms that require large capital investments upfront. In traditional methodologies, engineers develop and assess a set of candidate concepts, making use of industry’s “rules of thumb” and previous corporate experience to identify the most promising concept. However, this approach is time consuming and does not take into account all the possible technical solutions; therefore, there is a chance that good concepts can be missed in unexplored portions of the design space. Additionally, research in the field has traditionally focused on the optimization of oil fields concepts, such as in (Lin et al. 2009) (Barnes, Kokossis & Shang 2007) (Goel et al. 2006) (Iyer et al. 1998); however, this research does not address the architecting question of a single oil platform and the question of developing system concepts for an oil field development composed by multiple facilities and multiple reservoirs given broad project requirements.

This paper presents an integrated system architecture methodology for the evaluation of concepts for the architecture of complex systems with an application to oil and gas exploration and production platforms. Furthermore, it shows how a Design Structure Matrix (DSM) is integrated to provide an effective tool for visualization and management of complexity in the analysis of large offshore projects. The architecting methodology addresses the conceptual assessment at the early stages of the design process, and is based on five fundamental steps (Figure 1), which are used to perform an exhaustive exploration of the design space of system concepts in a limited timeframe. The intent is to improve the state of the art by capturing the design logics with which concepts’ assessment is made, and embed it into a structured algorithm (Architecture Decisions Graph (Simmons 2008)) that is able to enumerate and evaluate all the technically feasible system architectures available in OGM. The main advantages of such an approach are that a complete and automated exploration of the design space can be performed quickly and using the same information database and logics employed by experts, whose involvement traditionally requires several iterations and weeks to perform. One of the hardest aspects of making the right concept selection is demonstrating rigorous elimination of unsuitable concepts; this methodology provides this aspect.

2 SYSTEMS ARCHITECTING METHODOLOGY

Figure 1 provides an overview of the 5-step methodology with its main output, a selection of promising system concepts for further and deeper analysis by the decision maker. The first step is the identification of architectural elements, which consists into the formal decomposition of the system into simpler and manageable aggregates and the identification of primary design parameters that are defined as the system’s characteristics that have a significant impact on the overall system performance. The second step involves an enumeration of all the feasible architectures. Successively, it is possible to develop multiple quantitative relationships – the value functions - based on the primary design parameters that are able to estimate the value of any given architecture (Step 3). Such value functions are then applied to the architectures that have been previously enumerated in order to perform an evaluation of architectures (Step 4), and rank them against some given metrics (Step 5).
Figure 1 Systems architecting methodology overview

3 ILLUSTRATIVE EXAMPLE

Step 1 (Identification of architectural elements): Figure 2 presents the structural morphological matrix that has been developed for the enumeration of offshore platform architectures. The first column groups the functions that an offshore platform is intended to do. The second column presents the forms and attributes, i.e. the physical elements of the system that are intended to perform system functions and the main subsystems needed, respectively. Then, successive columns present the different possible choices that can be implemented for the different attributes. A system concept is obtained by selecting one option for each form’s attribute. This process is regulated by a list of constraints, which prevent the generation of unfeasible architectures. Generated architectures are then assigned a unique ID for successive evaluation and reference.

Step 2 (Enumeration): The enumeration of all the feasible architectures is performed using an Architecture Decisions Graph (ADG) (Simmons 2008). ADG performs the enumeration based on the main architectural decisions that must be taken for the design of a system, given a set of requirements.

Step 3 (Development of value functions): Multiple value functions can be developed for the successive evaluation of platform concepts, such as lifecycle cost, technical risk, inherent safety, etc.. In the example described here, value functions have been presented to evaluate the capital expenditure (CAPEX) of an offshore platform. CAPEX data has been obtained by analyses conducted using Siemens Oil and Gas Manager®, a domain-specific software for the assessment of oil field concepts. As a measure of technical risk, data on technology readiness level (TRL) has been collected.

Step 4 (Evaluation of architectures): Figure 4 presents an example of architectures ranking based on CAPEX and TRL, which is essentially the output of Step 3 of the methodology. The dashed red line presents the Pareto front of architectures, i.e. the non-dominated concepts that feature the best combination of cost and risk (i.e. lowest CAPEX and highest TRL).

Step 5 (Identification of promising concepts): With the previous information, it is now possible therefore to identify the most promising architectures.
4 THE DESIGN STRUCTURE MATRIX AS A TOOL FOR COMPLEXITY MANAGEMENT IN OFFSHORE OIL AND GAS PROJECTS

The Design Structure Matrix can be used as an effective complexity management tool in the visualization and analysis of oil field development architectures. Figure 5 represents a notional example of a field development, in which there are ten reservoirs (denoted as R1, R2, …, R10), and two offshore platform facilities (denoted as F1 and F2). There are several types of connections between the elements in this system: the facilities are connected to the reservoirs through inbound pipelines that transport crude to the platform, and outbound pipelines that inject water into the reservoir to maintain its pressure and stimulate production. Furthermore, it is possible that facilities are connected together to share services such as the electric power supply. While this diagram representation is useful to visualize the connections between the elements, it is not an effective means of analysis of multiple field architectures. In fact, the scope of this research is to develop a methodology to explore the design space of field architectures, by assessing the Net Present Value (NPV) of the investment. For the calculation of the NPV, designers need to estimate the capital and operating expenditures of wells, pipelines connections and facilities for field architectures. The DSM is an essential tool in this endeavour: Figure 6 shows the DSM representation of the same notional example presented in Figure 5. The letters inside a cell represent the existence of a connection between two system elements, and the specification of its type; the cell allocation is also able to provide an insight on the directivity of the connection between elements. For example, the “P” in (F2,F1) represents the existence of a power line between facility 2 and facility 1. The advantages of this implementation are therefore manifold: immediateness in visualization is still insured for small DSMs, and for large matrices it is possible to implement a graphic tool to translate the matrix in Figure 6 in a diagram such as the one in Figure 5. Furthermore, the matrix is readily available for analysis and automatic enumeration of architectures using architecting tools such as OPN. Also, the DSM is able to convey a significant amount of
information efficiently, such as data on connectivity, directivity and type of connection. Therefore, the DSM represents an ideal tool for the analysis of the topology of an oil field development. It is acknowledged that NPV is not the only measure of a development concept – other factors and measures such as energy efficiency, CO2 emissions will need to be taken into account during concept selection.

5 CONCLUSION
A system architecture approach for the conceptual design of offshore oil and gas production platforms has been presented. It has been shown how the approach based on a five-step methodology is able to provide decision-makers a quantitative rationale for a down-selection of promising concepts for more detailed analysis and design studies. The proposed methodology embeds the same logics that is employed in traditional concepts assessment, and features the important advantage of being able to screen all the feasible concepts in a limited time frame (in the order of minutes), therefore allowing designers the analysis of different case studies in a more efficient way than traditional methods (that would require weeks of teamwork or extensive computations). This methodology is currently under refinement and several improvements can be made. Future work will include:

- The quantitative assessment of more sophisticated case studies composed of multiple offshore platforms over multiple oil and gas reservoirs, such as the one presented in Section 3. As presented, the DSM is a tool of paramount importance in the implementation of the numerical analysis in this research;
- The management of uncertainties, such as market uncertainties in the assessment of a project;
- The evaluation of other performance metrics, such as safety, programmatic risk and others. This will lead to the development of decision-making aiding tools, by improving the visualization, thus the understanding of the worthiness of a system concept in terms of value as measured by the value functions.

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7 REFERENCES

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