Application of Complex Systems Architecting Approach to Develop a Digital Twin

Application: Phosphate mining site of Benguerir

Makouar Kaltoum, Deshayes Laurent
ILO
UM6P
Benguérir, Morocco
Email : Kaltoum.makouar@um6p.ma
Email : Deshayes.laurent@um6p.ma

Mouchtachi Ahmed, Aitelmahjoub Abdelhafid
L.I.S.S.I.E.E
ENSAM
Casablanca, Morocco
Email: ahmedmouchtachi@yahoo.fr
Email: aitelmajoub@gmail.com

***Abstract*— The aim of this paper is to present the application of complex systems architecting approach in the development of the digital twin through a use case of an industrial process: phosphate mining site of Benguérir. We introduce the digital twin concept and its influence on the development of manufacturing processes. Further, we present the complex systems engineering approach and its added value to the design and the manipulation of systems with a higher level of complexity, and how this approach allows designing a digital twin model of the mining site. Previous work undertook the digital twin concept and its benefits on industry without mentioning an efficient method to develop it. To realize our vision to design the digital twin of the mining site of Benguérir, we used SysML diagrams to model the solution based on the three visions of the complex systems engineering: the operational vision, the functional vision and the constructional vision.**

Keywords- Industry 4.0; digital twin; simulators; complex systems engineering; mining site; fixed infrastructures.

I. INTRODUCTION

The fixed infrastructures of the mining site are a main process in its value chain, whose function is the physical treatment of the extracted product. It consists in separating rocks from valuable product and the transfer of this product to the other sites (chemical treatments); this process is composed of three units:

- Stone removal unit: The trucks bring the product (the phosphate) from the field, and put it into two hoppers, then it is screened, the rocks are crushed and sent to a waste rock storage and the product is sent to the next unit via conveyors.
- Screening unit: A second screen is necessary; the unit contains five screens and five hoppers; the product is now sent via conveyors to the loading unit.
- Loading unit: The product is stored and then loaded in specific wagons depending on the quality, the type and the quantity demanded from the customers.

The industrial manufacturing and, of course, the mining sites are getting into a deep transformation, which considers digital technologies getting into industrial equipment. This is the fourth industrial revolution, called Industry4.0. It is characterized by the fusion of virtual world of internet and the real industrial facilities.

There are three big challenges to face, in order to be able to pursue this transformation:

- Training: Industry 4.0's transformation requires not only to change equipment but also to change minds, operators should be aware of the new technologies and their use.
- Test and verification: The operator needs to change the configurations, edit the program, upgrade the system or maintain a new equipment, and this without any risk or failure, so, the operator must simulate and test the modification before implementing it in the real process.
- R&D: Engineers and researchers need to develop algorithms and new methods based on the data collected from the field and test the results and algorithms.

To face those challenges, and pursue the change, the Polytechnic University of Mohammed VI and the mining site of the Office Chérifien des Phosphates (OCP) adopted the digital twin concept to deal with the issues discussed before.

The digital twin is the virtual representation of a real process, product or service [1]; it contains of real time simulators and this representation is a complex system since it must be a very close model of the real system. Furthermore, a well-defined design process should be used in order to collect all requirements from all stakeholders. The complex engineering system approach provides a structured and flexible modelling methodology in order to implement and develop a clear functional architecture.

The aim of this paper is to present the impact of complex systems architecting approach in developing the digital twin of the mining site.

After first describing the principles of systems engineering approach and the digital twin concept, this paper then demonstrates how this approach is an effective methodological support and allows an early detection of possible weaknesses during initial design stages.

The paper is structured as follows: In Section 2, a state of art will be presented, then Section 3 is dedicated to the definition of digital twin concept and its advantages. Furthermore, the complex systems architecting method is presented is Section 4, while Section 5 will present the application of the complex systems architecting method in the process of the mining site and results of this work, and we conclude with a conclusion and perspectives of the work.

 ISBN: 978-1-61208-672-9

II. STATE OF ART

Different understandings of the digital twin can be observed in industrial practice. In this regard, it has been argued that Parametric Technology Corporation (PTC) is focusing on establishing a link between the virtual product model and the physical part to increase the manufacturing flexibility and competitiveness, while Dassault Systèmes targets the product design performance. Moreover, the digital twin understanding of General Electric focuses on forecasting the health and performance of their products over lifetime, whereas SIEMENS strives for improved efficiency and quality in manufacturing. TESLA aims at developing a digital twin for every built car, hence enabling synchronous data transmission between the car and the factory, while other companies increasingly use complex product models to boost the immersion in virtual and augmented reality applications [2].

To develop a flexible digital twin framework and satisfy the multiple understandings, a developed architecting method should be adopted, and as the system is complex and provides many parameters, this work proposes the complex systems architecting method to model and implement the digital twin based on simulators.

The design and development of a system indeed requires the contribution of various processes, stakeholders and techniques. Each person often concentrates on a specific aspect of the system without any perspective on the other aspects: designers have an architectural and functional vision of the system, the manufacturing team considers a system as an element to be integrated in the assembly line, the procurement department views it as a list of supplies to be purchased. Complex systems engineering thus enables a global view of the system to guarantee the consistency of specific contributions to the system; it takes into account the whole life cycle of the system including the definition of customer requirements, design, production, and marketing. It defines the most effective methods and means for satisfying the technical and organizational requirements which, in practice, means satisfying cost, time and productivity constraints. The challenge of complex systems engineering is to design and product the best system to meet a customer's requirements with the most efficient control of deadlines and costs. As system complexity continues to increase, systems engineers now use modelling techniques to guarantee that specification and design models are correctly built and can be easily communicated to the development teams [3].

The objective of the work described in this paper is to demonstrate the advantages of using recommended methodology for the development of complex systems.

III. DIGITAL TWIN CONCEPT

First, the project of the digital twin (DT) was originated in the Institute of Automation, Measurement and Applied Informatics of the faculty of Mechanical Engineering of the Slovak University of Technology in Bratislava [4]. The DT is one of the main concepts associated with the new industrial revolution, Industry 4.0. Manufacturers are taking a more systems-design approach by implementing rigorous systems-design processes that accommodate the complexities of developing multi-disciplinary systems. Digital twins are at the core of this development process [5].

The digital twin can allow companies to have a complete digital footprint of their products from design and development through the end of the product life cycle. Digital twins are designed to model complicated assets or processes that interact in many ways with their environments for which it is difficult to predict outcomes over an entire product life cycle, and to solve physical issues faster by detecting them sooner, predict outcomes to a much higher degree of accuracy, design and build better products, and, ultimately, better serve their customers [6].

IV. COMPLEX SYSTEMS ENGINEERING APPROACH

Complex systems engineering approach is the whole activity that allows to design an optimal system to meet a need. It is based on system vision that includes multiple parameters, the multidisciplinary aspect, the life cycle and the use cases. It consists of establishing the functional and physical compatibility of a system with the needs and the constraints

Systems engineering approach enables engineering organizations to proceed toward the design of complex systems and its impact across multiple engineering disciplines: mechanical, electrical, and software. With this approach, customer requirements are defined early in the development cycle and are implemented through design and system validation—from concept to operation [7]. This approach is based on three essential visions: Operational vision, functional vision and constructional vision.

- Operational Vision: The operational vision provides “black box” models [8] of a given system where one describes the interactions and the interfaces of a system of interest with its environment. Its core motivation is to understand the “Why” – of the system.
- Functional Vision: The core notion of the functional vision is to understand the “what” of the system, it functions, and the main mission is to understand deeply what does the system without however knowing at this point how it is concretely structured.
- Constructional Vision: The aim is to describe all concrete hardware, software and human-ware components of a system with their interactions; all constructional concepts, such as configuration, constructional scenarios or constructional objects are again uniquely referring to the system of interest without involving any external system [9].

V. APPLICATION & RESULTS

In order to implement the complex systems engineering approach, we have employed the SysML modeling language to develop different diagrams for each vision.

The results of applying each vision are the operational, the functional and the constructional diagrams; those diagrams will facilitate to develop the digital twin of the mining site. This method is characterized by high precision, accurate functioning and various configurations.

A. Operational vision

The aim of the operational vision is to identify the multiple users of our system and its environment, also to understand the stakeholders and the interactions between them. It facilitates to design our system with high precision because a misunderstanding or an error occurred during the operational architecture process may lead to costly and disastrous consequences on our system under development.

Fig.1 below describes the use cases of our system. The digital twin of the OCP mining site will be used by multiple stakeholders which are: Operators, supervisors, production agents, maintenance agents and office managers. Its use cases are: the test of the configurations, the optimization of process, the simulation of the process, prediction of the system performance, real time monitoring and also for the production management.

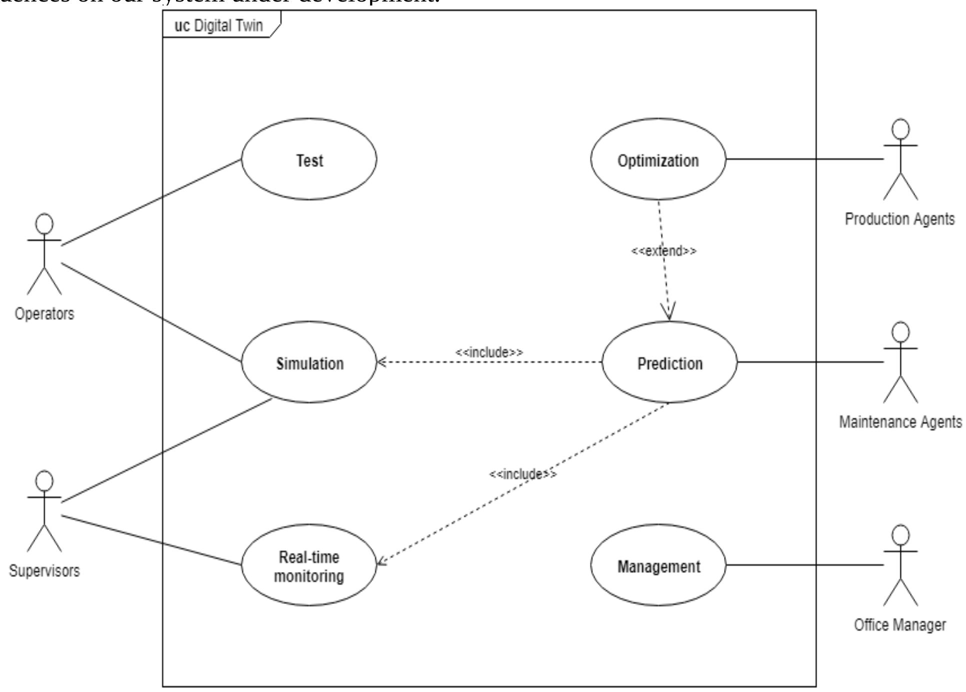

Figure.1: Use cases diagram of the digital twin

B. Functional vision

The results of the treatment of this vision are the functional requirements of our system (the digital twin) which are the functional needs of the operators from the field, agents, engineers and office managers. We will present the results of applying the functional vision of complex system engineering to develop the functional diagrams that will serve to develop the digital twin of the mining site.

As mentioned before, requirements engineering is an essential part of systems engineering. Indeed, understanding the need facilitates designing the solution. Every requirement should be S.M.A.R.T: Specific, Measurable, Achievable, Relevant and Traceable [10].

Operators express their needs and the challenges they face by writing texts and classical sentences, e.g., The stacker needs to be automated; the provider of the solution may have different reflections and challenges to design the right and exact solution for the problem. The aim of this work is to identify the real needs of the operators, to model those needs in a flexible way based on a system modeling language and use the requirements model to verify and validate the solution proposed to implement the digital twin.

Fig.2 below describes the functional requirements of our system. Those requirements have been identified from the users of the digital twin. We classified them into four sections: Simulators, Research and development (R&D), Training and test and validation. We have also set the requirements for each section in order to model those requirements in a flexible way.

Copyright (c) IARIA, 2018. ISBN: 978-1-61208-672-9

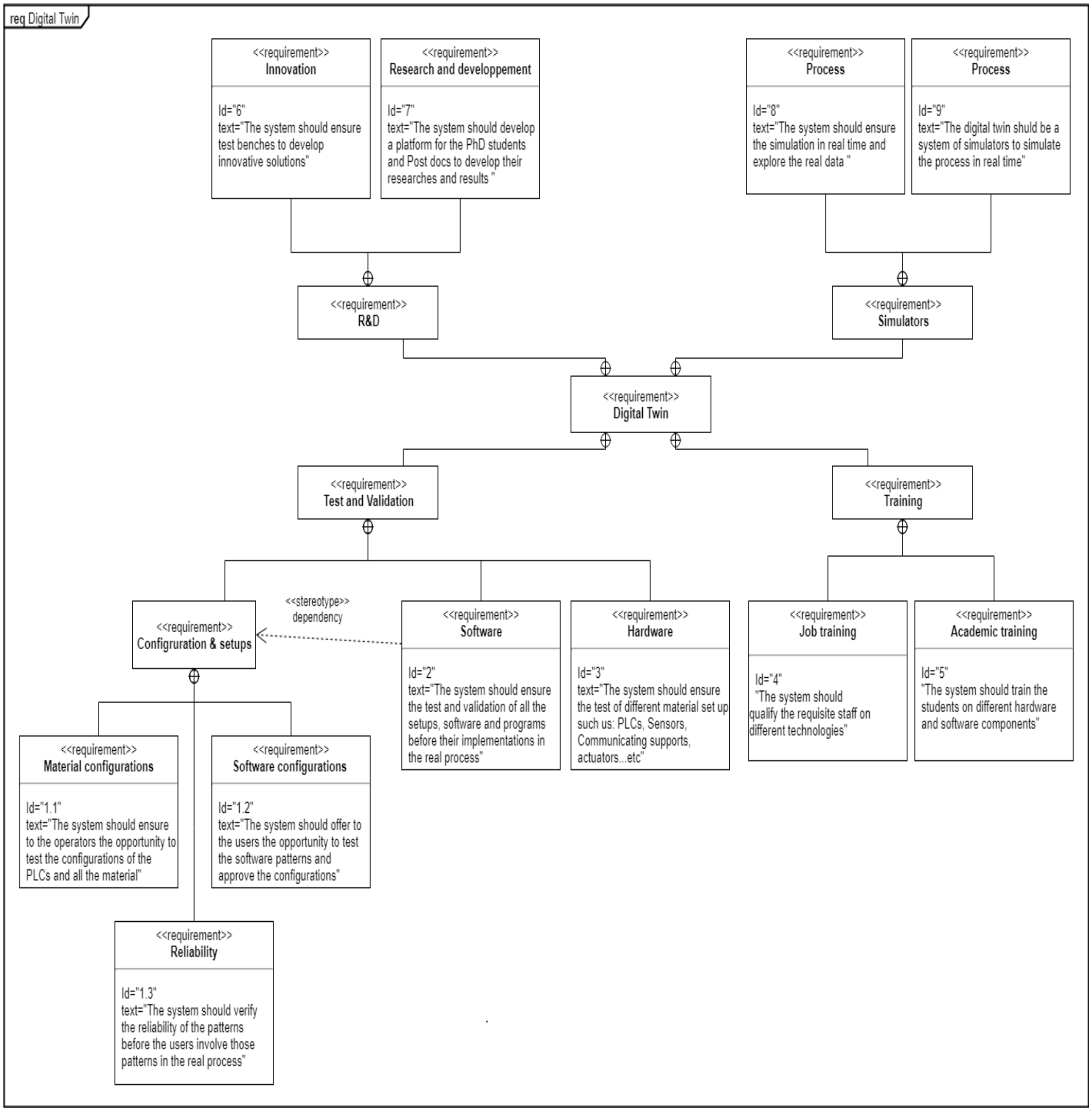

Figure.2: Functional Requirements diagram of the digital twin

C. *Constructional vision*

Constructional architecture is key since it consolidates all architectural analyses in a concrete vision of the considered system. It makes in particular the synthesis between a top-down design approach, as provided by the systems architecting process, and a bottom-up one, which is typically induced by the constraints due to the existing product architecture or by the new possibilities brought by the advances of technology [11].

Fig.3 shows the definition block diagram of the digital twin. This system is composed of n number of PLCs, motors, actuators, sensors, panels and computers. The definition block diagram shows the components of the digital twin, their parts, their values and the ports of the material and the energy of those components.

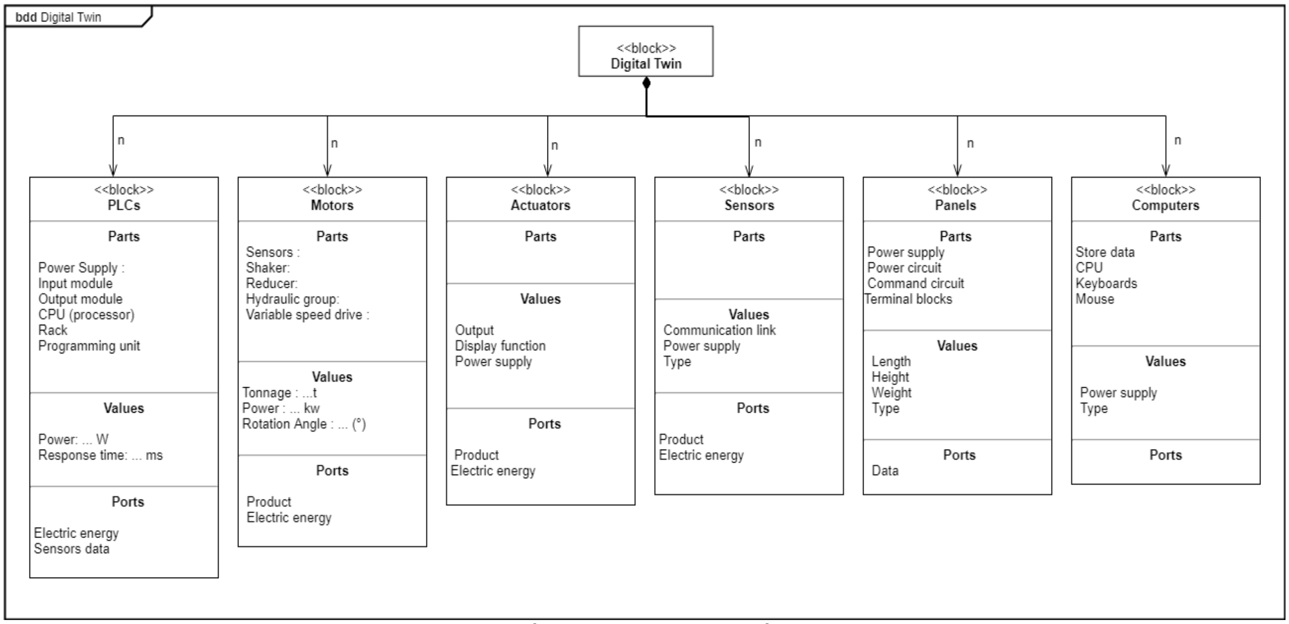

Figure.3. Definition block diagram of the digital twin

Those diagrams will be used to establish the physical architecture of the digital twin of the fixed infrastructures with all the components.

VI. Conclusion and Perspectives

The mining site of OCP and the Polytechnic University of Mohammed VI are pursuing the digital transformation by developing innovative and advanced solutions for mining and chemical processes. The example of this project is a good demonstration that the complex engineering systems approach is a powerful tool to design future advanced and fully digitalized systems and to optimize existing mining systems. The results obtained in this work, which are the operational, the functional and the constructional diagrams of the digital twin of the mining site will be used to implement our digital twin; they facilitate modeling the global architecture of our system and maintain its flexibility. In addition, it allows to test the automation solutions and advanced technologies implemented in the digital twin and it helps to offer innovative technological solutions in order to implement an advanced model of control and real time monitoring of the mining site.

References

[1] E. Negri, L. Fumagalli, and M. Macchi, “A review of the roles of digital twin in CPS-based production systems”, Modena, Italy, p. 427, June 2017.

[2] B. Schleich, N. Anwer, L. Mathieu, and S. Wartzack, “Shaping the digital twin for design and production engineering”, Germany, p.2, 2017.

[3] G. Auriol, C. Baron, and J. Y. Fourniols, “The advantages of systems engineering standards, a case study of application of the EIA632 standard to design of a small-scale yacht”, Toulouse, France, p.2, 2011.

[4] M. Morhàc, M. Moksik, J. Vanchalek, L. Bartalsky, O. Rovny, and D. Sismisova, “The digital twin of an industrial production line within the industry 4.0 concept”, Štrbské Pleso, Slovakia, p. 1, June 2017.

[5] P. Goossens, “Industry 4.0 and the Power of the digital twin”, Canada, p. 4, September 2017.

[6] A. Parott, L. Warshaw, Deloitte University Press, “Industry 4.0 and the digital twin Manufacturing meets its match”,USA, p. 2, May 2017.

[7] EETIndia, “Advantages of systems engineering approach”, p. 2, October 2013.

[8] CESAM Community, CESAMES Systems Architecting Method, A Pocket Guide, p. 42, January 2017.

[9] CESAM Community, CESAMES Systems Architecting Method, A Pocket Guide, p. 46, January 2017.

[10] White book, Requirements engineering for an information system, Compliance Consulting, p .11.

[11] CESAM Community, CESAMES Systems Architecting Method, A Pocket Guide, p. 93, January 2017.