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Study and Analysis of Wind Power System using The Modeling Language SysML

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Abstract: Nowadays, we need to use renewable energy sources to generate power and support the growing demand for electricity and also to protect the environment from carbon gas. However, wind power is one of the alternatives for generating electricity. For this reason, our paper aims to achieve a functional, structural, and behavior description of a wind power systems using the systems modeling language SysML. In this paper, we start with presentation of wind power system. Next, we describe the systems modeling language SysML. Subsequently, we present the modeling results of wind power system based on SysML diagrams. Finally, concludes this paper with some prospects.

Keywords: Wind power system, systemic approch, modeling language SysML.

1. Introduction

The smart grid contains seven areas, the most important one is the production area, which is a large research area generally based on the renewable sources. The renewable sources of energy are the cleanest, the most economical, nonpolluting, ecological character and overlooked their costs they are free and will never risk to be annihilated.

Wind power is one of the renewable sources of energy. It's one of the alternatives for generating electricity [1]. However, this latter has been used since early history to provide mechanical power to pump water or to grind grain. However, windmills and water driven mills were the only power generators for over 1200 years predating the 18th Industrial Revolution. Later, evolution and perfection of these systems was performed step by step in Denmark, France, Germany, and the UK [2].

Wind power isn't exactly a new idea, contemporary societies are essentially based on fossil fuels for covering their increasing electrical energy demand. But actually, security of energy supply, increasing demand and environmental issues has captivated the interest for renewable sources of energy such as wind turbine system.

In order to understand the overall operation of the wind power system, we propose a high-level graphical description using the SysML diagrams.

In this paper, we start with presentation of wind power system in section 2. Next, the system modeling language SysML is presented in section 3. Functional, structural, and behavior description of a wind turbine using SysML diagrams is shown in section 4. Finally, some conclusions are presented in section 5.

2. Presentation of wind power system

Wind power is mostly the use of wind turbines to generate electricity. Wind power is popular, sustainable, renewable energy source that has a much smaller impact on the environment than burning fossil fuels. Historically, wind power has been used in sails, windmills and windpumps but today it is mostly used to generate electricity.

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Wind turbine convert the wind's kinetic energy into electrical power [3]. It falls into one of two basic categories [4]:

- Horizontal axis wind turbines (HAWTs).
- Vertical axis wind turbines (VAWTs).

In the figure 1, we identify the different blocks of a wind conversion chain. This is why we start by modeling of turbine, the multiplexer, the generator and finally the converter [5], [6], [7], [8].

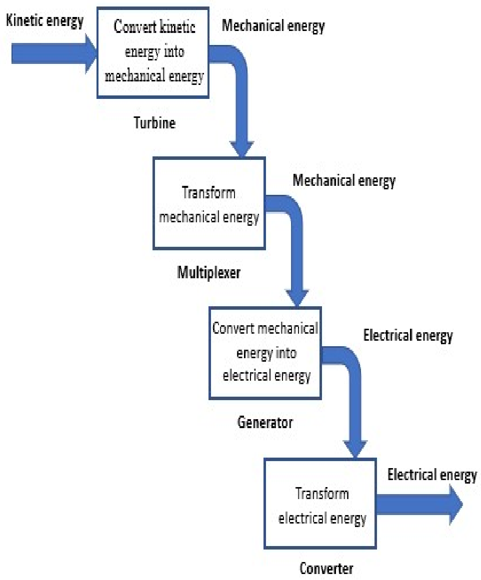

Fig. 1 Different blocks of a wind power conversion chain

3. Presentation of system modeling language "SysML"

The System Modeling Language "SysML" is a domain-specific modeling language for system engineering. It allows specification, analysis, design, verification and validation many systems. Originally, SysML was developed as part of a specification project open source, and includes an open-source license for its distribution and use [9], [10], [11].

SysML diagrams can be divided into three types:

- Diagrams that capture system requirements (requirements diagram).
- Diagrams that describe the structure of the system (internal block diagram and block definition diagram).
- Diagrams that describe the behavior of the system (use case diagrams, sequence diagram, activity diagram, and state machine diagrams).

Figure 2 presents the SysML diagram architecture.

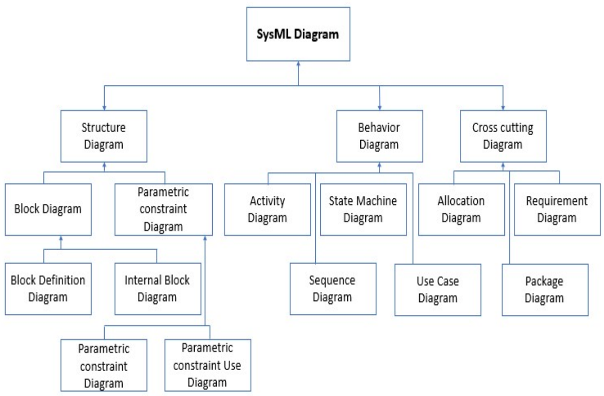

Fig.2 SysML diagram architecture

The benefits of SysML modeling are to share complex system specifications, identify risks, and create a basis for analysis. The SysML also facilitates the management of complex systems.

In the literature, we find many applications that have been used to develop design of renewable energy systems. We present here some studies that have been presented in various researches:

Researchers Labiadh.N et al. [12], have used the SysML modeling language to describe the structure, function and behavior of a microgrid system. These descriptions identify the interactions, data flows, and control between parts of the system that are essential to understanding overall performance and can help in optimizing and designing future power grids, as well as in gaining a better understanding of how the system itself works from the perspective of a multidisciplinary approach.

Researchers Gutierrez et al. "have presented a methodology for modeling photovoltaic systems in embedded hardware. This methodology uses the HiLeS platform to transform SysML models in Petri nets and generate VHDL code. The proposed methodology is intended for Hardware-inthe-Loop simulations of power converters and PV panels in microgrids. In addition, this methodology allows the design of MPPT controllers for their direct implementation in FPGA" [13].

Researchers Gutierrez et al. "have described a methodology for implementing in FPGA models of photovoltaic panels for Hardware-in-the-Loop (HIL) and realtime simulations. The proposed methodology integrates numerical solutions, SysML diagrams and Petri nets for structural design and formal validation. In this study, photovoltaic cells have been modeled using the single diode circuit. The photovoltaic panel model is solved by the Newton-Raphson method, and the Lagrange remainder is employed to limit the iteration number. Results show suitable accuracy and performance of the proposed methodology" [14].

Researchers Gezer et al. "have described a methodology and a case study through which system architecture and dynamic models of related system components are gathered in order to design and simulate the SCADA system of a new hydro turbine test laboratory. System architecture model is prepared in SysML, a system modeling language based on UML, while the dynamic model of the laboratory is formed in Matlab/Simulink. Some simulations are performed in order to verify the preliminary system design studies and system requirements" [15].

Researchers Neureiter et al. "have explained that the current integration of decentralized, renewable energies is a main challenge for today's power system. In order to control the volatile behaviour of these Distributed Energy Resources (DER), the electricity system has to develop towards a Smart Grid. The development of this critical and complex System-of Systems involves different stakeholder from different disciplines. Thus, domain specific engineering concepts on system level are wanted. To foster the interdisciplinary development, the proposed approach presents a standards-based architecture framework, implemented as Domain Specific Language (DSL). Moreover, the DSL is used to develop a reference architecture on basis of the NIST Logical Reference Model. To evaluate the applicability of the reference architecture model it is used for instantiation of a particular system solution" [16].

Researchers Hodgson and al. "have discussed the principal mechanism for achieving the policy goal of the diminution of greenhouse gas emissions is the widespread electrification of transport and heating coupled with the parallel de-carbonization of electricity generation. This requires a main expansion of renewable generation jointly with new nuclear and clean fossil. This paper reviews both the policy position inside the UK and the implications for system balancing that large-scale intermittent generation, such as wind, presents to the System Operator (SO). One suggestion for helping to preserve system balance is the use of Demand Response (DR) by the SO. It is by no means clear whether the existing industrial structure can provide the right incentives for the realization of significant DR capacity. This paper presents a method of classifying barriers and describes experience in developing a Systems Engineering methodology, using SysML, as an approach to modeling the structural and operational aspects of the British system with the objective of considerate barriers to the execution of DR" [17].

Researcher Kaitovic and al. "have explained how economical and environmental concerns push toward novel solutions for sustainable, renewable and intelligent energy power grid - the Smart Grid. Such complex system, or better aggregation of systems, involve a number of various stakeholders coming from different areas of expertise, requires novel ICT solutions, etc. Even so, on-going projects do not apply unique formal design methodology and language. In order to better correlate the projects, improve understating of system requirements and simplify system design by decomposing its complexity a model driven methodology (MDM) and SysML could be applied. Applying MDM should give a possible referent model for aggregations in future Power Grid" [18].

Researchers Hodgson and al. "have discussed the principal mechanism for achieving the policy goal of the diminution of greenhouse gas emissions is the widespread electrification of transport and heating coupled with the parallel de-carbonization of electricity generation. This requires a main expansion of renewable generation (principally wind) jointly with new nuclear and clean fossil. This paper reviews both the policy position inside the UK and the implications for system balancing that large-scale intermittent generation, such as wind, presents to the System Operator (SO). One suggestion for helping to preserve system balance is the use of Demand Response (DR) by the SO. It is by no means clear whether the existing industrial structure can provide the right incentives for the realization of significant DR capacity. This paper presents a method of classifying barriers and describes experience in developing a Systems Engineering methodology, using SysML, as an approach to modeling the structural and operational aspects of the British system with the objective of considerate barriers to the execution of DR" [19].

In the next section, we describe the functionality of a wind power system using the SysML language.

4. Modeling results of wind power system

In this section, we describe the functionality of a wind power system using the SysML language. First, we present a functional modeling with use case diagram. Next, a complement to functional modeling with requirements diagram. Then, we present a modeling the behavior with sequence diagram and a structural modeling with BDD. Finally, we present a modeling with state machine diagram.

4.1 Functionnal modeling with use case diagram

The use case diagram is a functional diagram. it shows the functional interactions of the system. It precisely delimits the system and describes what will do. The use case diagram expresses the services offered by the system to the users. It represents the external functional behavior of the system in Fig.3.

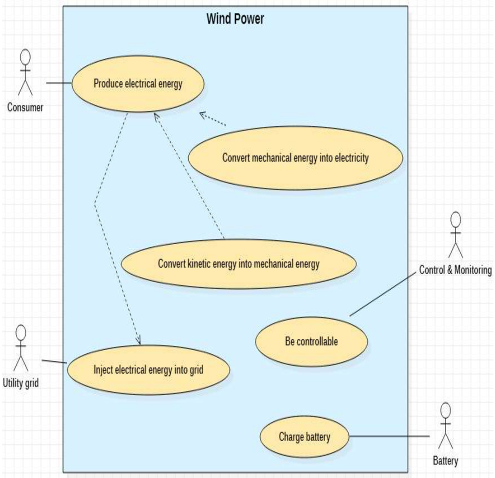

Fig.3 Modeling with use case diagram

4.2 Complements to functional modeling with requirements diagram

The requirements diagram is a functional diagram. It describes the requirements of the functional specifications. A requirement can express a function to be fulfilled by the system or a technical or physical condition... Its role is to specify the needs of the system. Fig.4 presents the functional requirement diagram.

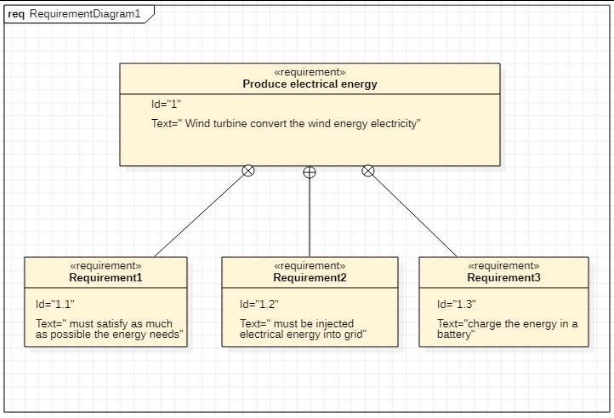

Fig.4 Modeling with requirement diagram

4.3 *Structural modeling with BDD*

The block definition diagram (BDD) is a static diagram. It shows static bricks, blocks, composition, association...

This diagram is used to describe the hardware architecture of the system. A block models the entire system, a hardware or software element. Fig.5 presents the block definition diagram.

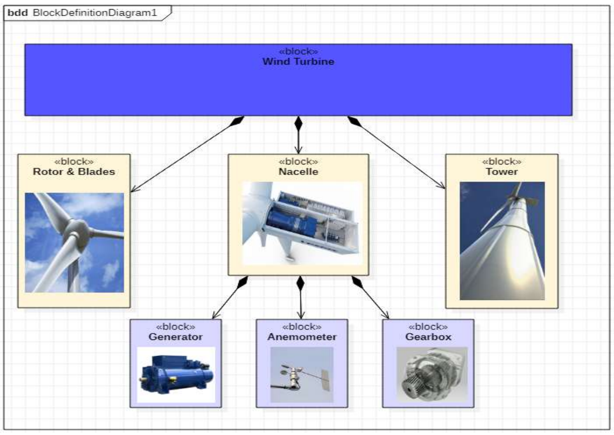

Fig.5 Modeling with block definition diagram (BDD)

4.4 Modeling the behavior with sequence diagram

A Sequence diagram is a dynamic behavioural diagram that shows interactions (collaborations) among distributed objects or services via sequences of messages exchanged, along with corresponding (optional) events (Fig.6).

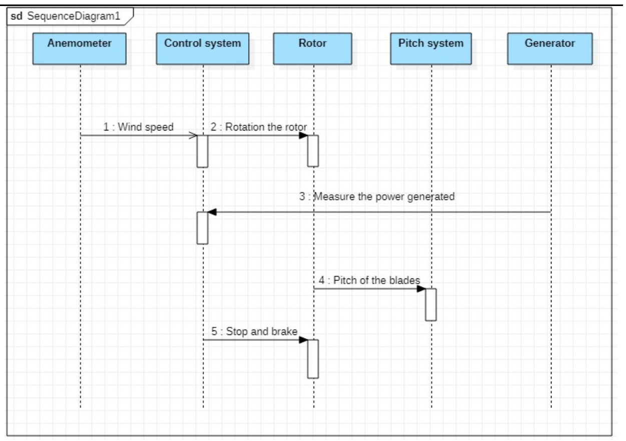

Fig.6 Modeling with sequence diagram

4.5 Modeling with state machine diagram

The state diagram is a dynamic diagram. It shows the different successive states and the possible transitions of the dynamic blocks. It represents the succession of states of a system or a subsystem. The dynamic of change is maintained by events. Fig.7 presents the state machine diagram.

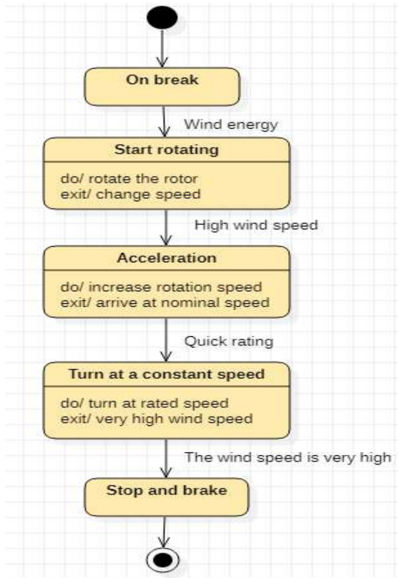

Fig.7 Modeling with state machine diagram

5. Conclusion

In this paper, we have described the functionality of a wind power system using the graphical modeling language SysML. These descriptions identify interactions and flow of data and control between parts of the system which is necessary to understand the overall operation of the wind power.

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