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Model Based Systems Engineering Concepts and Methodologies for Modeling of Renewable Power Plants

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Model-Based Systems Engineering (MBSE) is the formal application of a model-centered methodology for the design activities of engineered systems, being especially useful to support design requirements verification and validation of complex systems. The complexity of a system can be measured according to the number and relationships of the system elements. The design of renewable power plants has grown in complexity in last few decades, due to the integration of new technologies and the application of grid-code requirements. In this paper, a review of MBSE main concepts and leading methodologies (processes, methods, and tools) will be made with the objective of analyzing its application on the renewable power plants modelling and design.

MBSE CONCEPTS

- ***Systems Engineering***

An interdisciplinary approach to enable the successful realization of engineered systems.

- ***System***

An integrated set of interacting elements, subsystems, or assemblies organized to satisfy a system context.

- ***Model***

A simplified representation of a real system from a particular view or system context, with the intention to assist the understanding of the real system

- ***Model-Based Systems Engineering***

The formalized application of modeling to support system requirements, design, analysis, verification, and validation activities.

MBSE METHODOLOGIES REVIEW

- ***INCOSE Object Oriented System Engineering Method (OOSEM)***

Traditional top-down process, scenario driven approach. Objectives: i) Capture as much information as necessary, throughout the life cycle of the system, to specify, analyze, design, verify and validate the system; ii) Integrate MBSE methods with object-oriented software and/or hardware; iii) Support system-level models and design reuse. Language: UML/SysML.

- ***IBM Rational Telelogic Harmony-SE***

It is service request-driven, model-based, "Vee" process approach. The model and requirement's artifacts are maintained in a centralized repository. Objectives: i) Identify or derive required system functionality; ii) Identify associated system states and modes; iii) Allocate system functionality and modes to a physical architecture. Language: UML/SysML. Software: IBM Rhapsody.

- ***Vitech MBSE Methodology (STRATA)***

Uses an incremental process known as "Onion Model." Its process supports top-down, reverse engineering and middle-out system approaches, defining sub-activities for each system approach. It distinguishes three system concepts: the system context, the system under design, and the system used to design the system. Language: SDL. Software: CORE and GENESYS.

- ***ARCADIA***

Focused on structure and functional analysis. Provides robust ways of dealing with strong constraints. Introduces a metamodeling concept, defined by interlinked diagrams of interdisciplinary elements. Four levels of engineering perspectives: i) Operational analysis; ii) System analysis; iii) Logical analysis; vi) Physical analysis. Language: ARCADIA. Software: Capella (open-source).

RENEWABLE POWER PLANTS AS COMPLEX SYSTEMS

Complexity can be defined as "a measure of how difficult is to understand how a system will behave or to predict the consequences of changing it."

Complex Systems Principles	Renewable Power Plant Grid-connected Converter	MicroGrid, SmartGrid
1. Autonomous interacting parts (heterogeneous elements)	N	Y
2. Self-organization	Y	Y
2.1 Energy in and out (examples)	Y	Y
3. Display emergent macro-level behavior	Y	Y
3.1 Nonlinearity	Y	Y
3.2 Non-hierarchy and central authority	N	N
3.3 Various scales of structure	Y	Y
4. Adapt to surroundings (environment)	Y	Y
4.1 Become more complex with time; increasingly specialized	Y	Y
4.2 Elements change in response to pressures from neighboring elements	Y	Y

RENEWABLE POWER PLANTS AS CYBER-PHYSICAL SYSTEMS

Cyber-Physical Systems (CPS) refer to the "integration of computation with physical processes whose behavior is defined by both cyber and physical parts of the system.

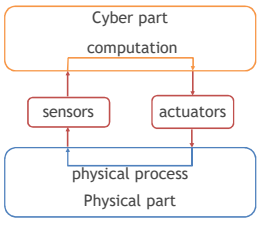

Fig. 1 Interaction between the cyber and physical parts of a cyber-physical system (CPS)

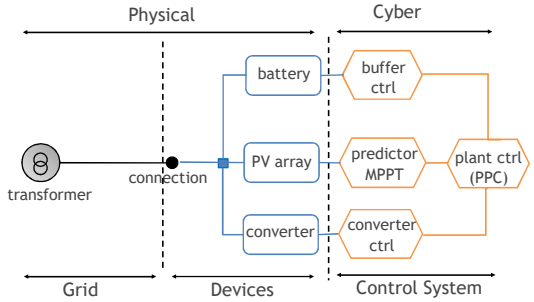

Fig. 2 Cyber-physical topology of a typical PV power plant

CONCLUSIONS

- MBSE has proven to be a powerful design technique for complex and cyber physical systems that require the integration of interdisciplinary analysis and tools.
- Renewable power plants are highly complex systems and can be designed and modeled focusing on structure and operational analysis, for the compliance of strong constraints, such as cost, performance (grid code requirements), safety and security. For this purpose, the ARCADIA/Capella methodology has been found to be more suitable.
- Renewable power plants can be analyzed as cyber physical systems where control plays an important role on their overall performance. For the design and modeling of renewable power plants from their control's perspective, the OOSEM and the Harmony-SE/Rhapsody methodologies have been found more suitable.

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