

Engineering Challenges in the Smart Grid

The development of Smart Grid systems has proven to be a challenging task. Besides the inherent complexity of such closely interacting, distributed systems, the nature of the Smart Grid requires outstanding scalability capabilities.

In addition, typically numerous different stakeholder from different domains and disciplines are involved in the development of Smart Grid systems.

To support the development of robust systems in contempt of these difficulties, adequate engineering approaches are to be elaborated.

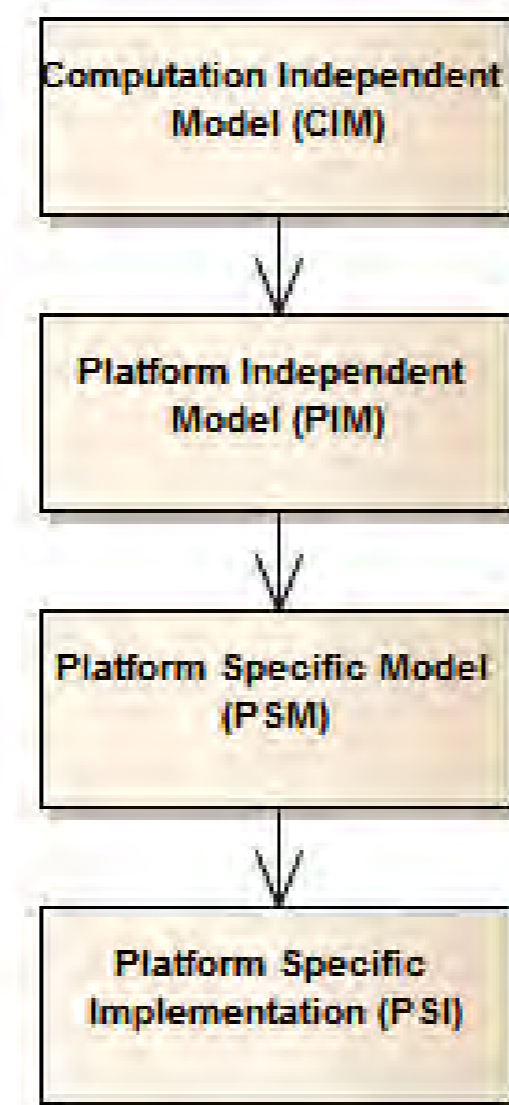
Model Driven Architecture (MDA)

Model Driven Architecture (MDA), as introduced by the Object Management Group (OMG) [2], is a broadly accepted approach for handling the engineering of complex and interdisciplinary systems.

The utilized "separation of concepts" paradigm represents a suitable basis for communication and cooperation between various stakeholder with different viewpoints.

The model based development process can be organized by focusing on four basic artefacts:

- ▶ Computation Independent Model (CIM)
- ▶ Platform Independent Model (PIM)
- ▶ Platform Specific Model (PSM)
- ▶ Platform Specific Implementation (PSI)

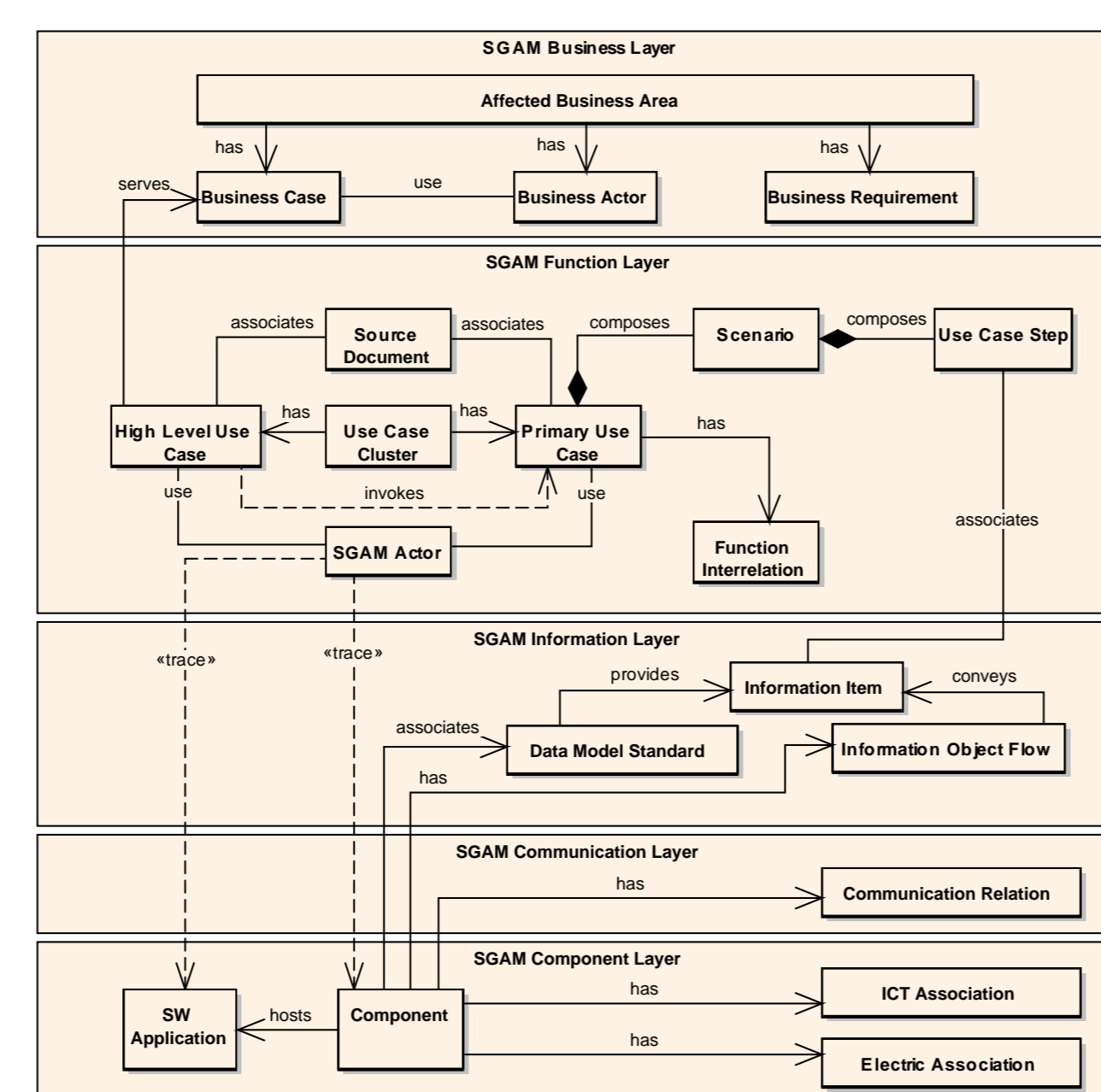
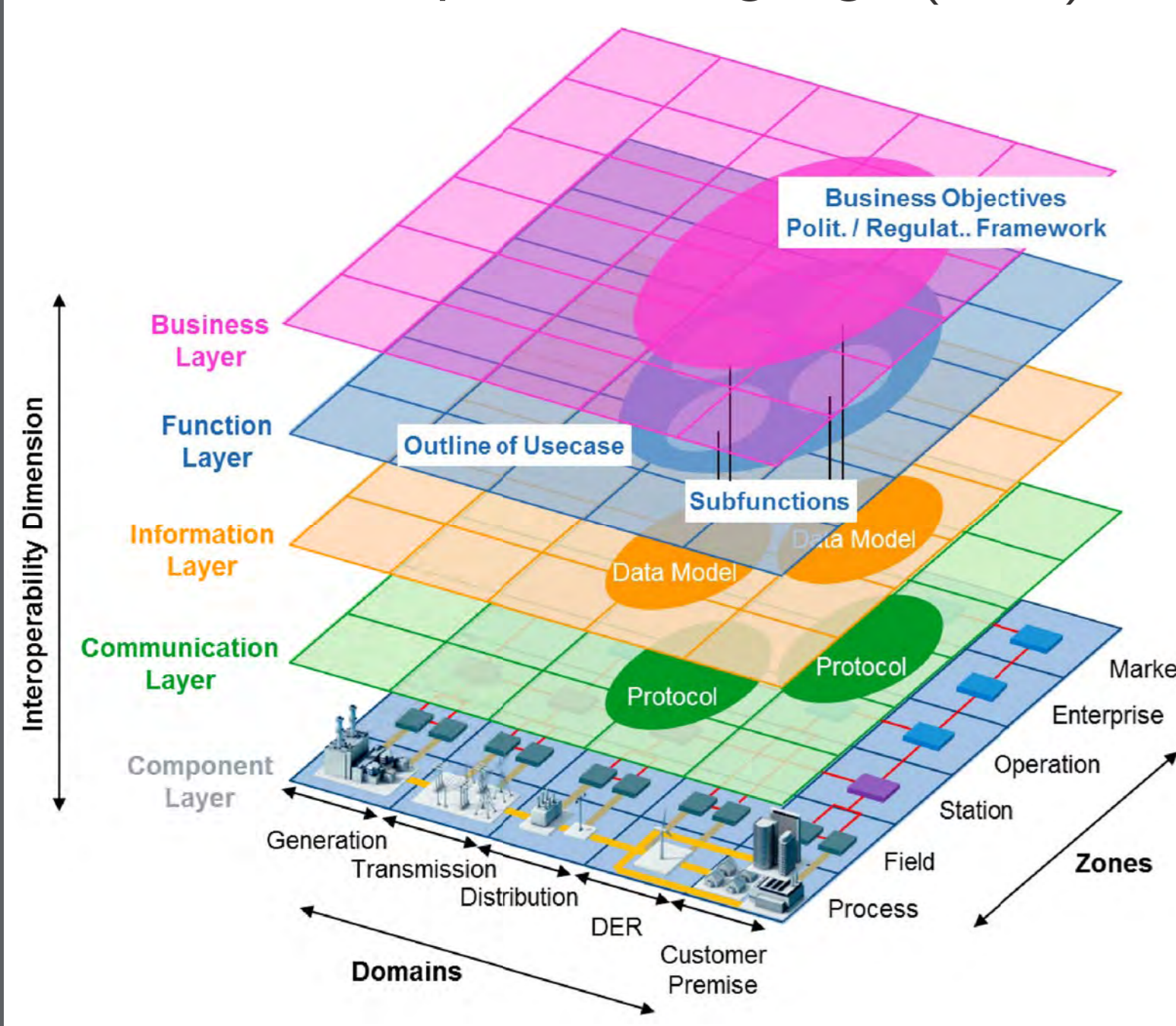


Central Task

The capabilities of MDA in the development of Smart Grid Systems should be evaluated. A domain specific MDA approach, consisting of a **Domain Specific Language (DSL)**, a tailored **Development Process** and an adequate **Toolbox** were developed and evaluated in different projects.

Domain Specific Language

In 2012 the Smart Grid Coordination Group (SGCG) announced the Smart Grid Architecture Model (SGAM) [3]. The SGAM can be utilized to develop a Domain Specific Language (DSL), represented by it's metamodel [1].



The Smart Grid Architecture Model (SGAM)[3]

The DSL Metamodel [1]

References

- [1] C. Dänekas, C. Neureiter, S. Rohjans, M. Uslar, and D. Engel. *Towards a model-driven-architecture process for smart grid projects.* In P. Benghozi, D. Krob, A. Lonjon, and H. Panetto, editors, *Digital Enterprise Design & Management*, volume 261 of *Advances in Intelligent Systems and Computing*, pages 47–58. Springer International Publishing, 2014.
- [2] Object and Reference Model Architecture Board Subcommittee. *Model Driven Architecture (MDA).* Technical report, Object Management Group, 2001.
- [3] Smart Grid Coordination Group. *Smart Grid Reference Architecture.* Technical Report November, CEN-CENELEC-ETSI, 2012.

Acknowledgements

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The SGAM Toolbox

The SGAM-Toolbox is implemented as extension to Sparx Systems Enterprise Architect modeling tool. It utilizes

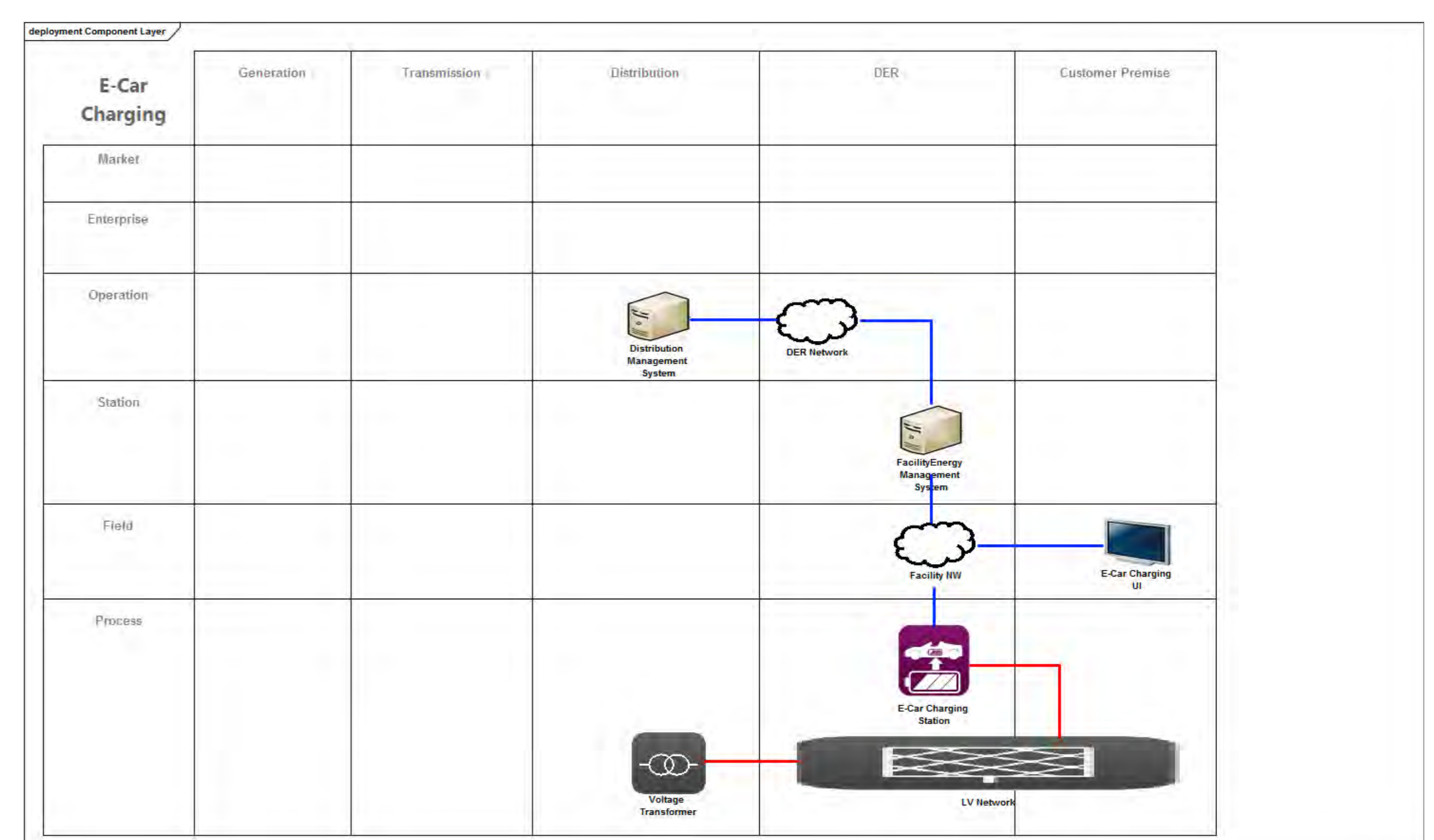
- ▶ Domain Specific Language as UML profile implementation
- ▶ Templates, Tutorials and Reference Examples
- ▶ Requirements Engineering methodology with focus on privacy and security requirements
- ▶ Input- and Output for Key-Performance-Indicator (KPI) estimation
- ▶ Heatmaps for visual analytics

Evaluation

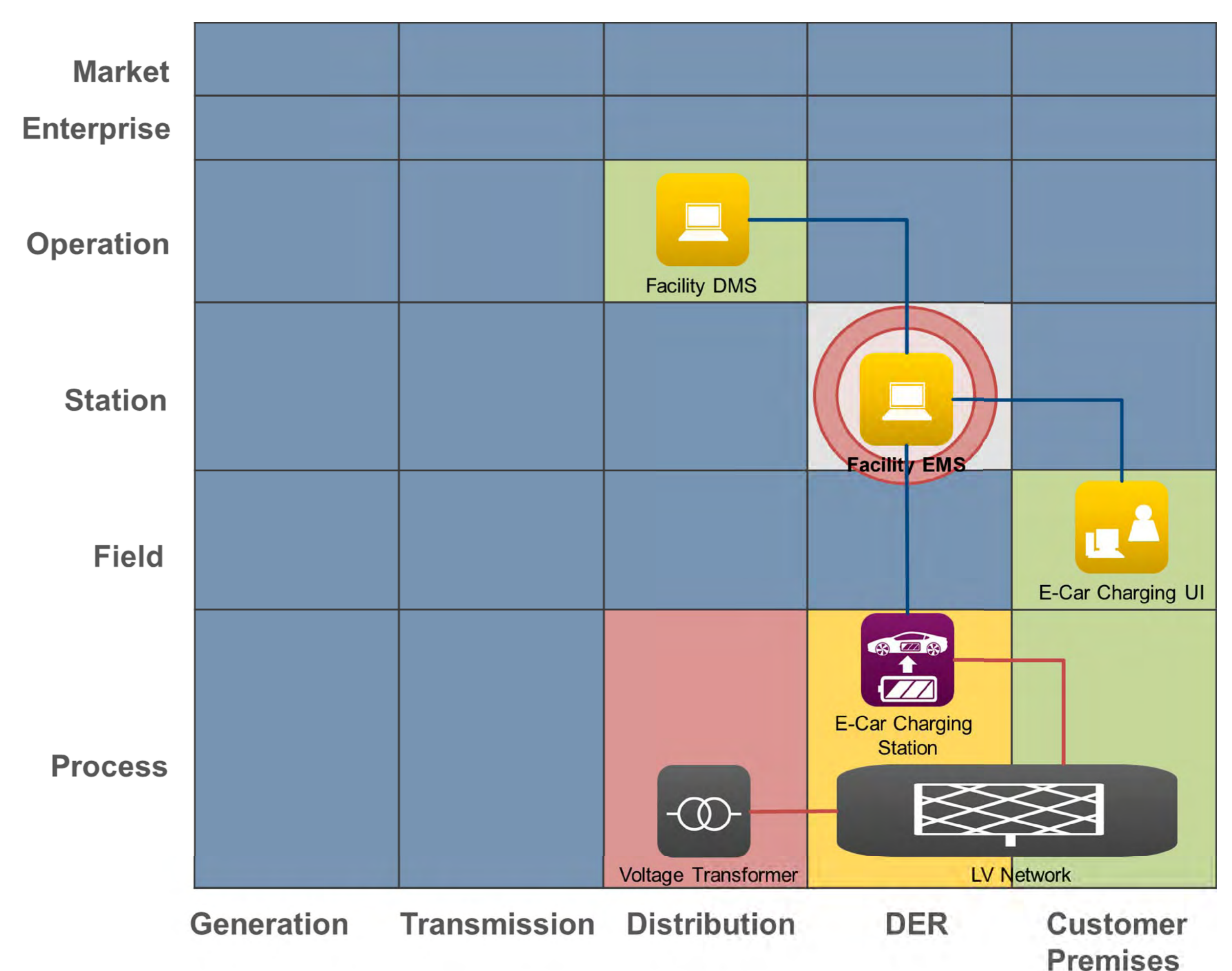
The SGAM-Toolbox is utilized and evaluated in different research projects.

- ▶ Project INTEGRA
 - ▷ Deriving a secure Reference Architecture for Smart Grid systems out of numerous real-world demonstration projects.
- ▶ Project DISCERN
 - ▷ Assessment of the optimal level of intelligence in the distribution networks by utilizing the experiences of different projects in europe.

SGAM Component Layer



Heatmap



Current Research Activities

- ▶ Key Performance Indicator (KPI)
 - ▷ Ontology based Privacy Assessment
 - ▷ Dependability estimation with Markov Chains
- ▶ Requirements Engineering
 - ▷ Deviation of Security Requirements
 - ▷ Deviation of Privacy Requirements
- ▶ Model Driven Development (MDD)
 - ▷ Integrated and semi-automated development workflow
 - ▷ Based on SGAM architectures