MULTI-LAYERED RELIABILITY ANALYSIS IN SMART GRIDS

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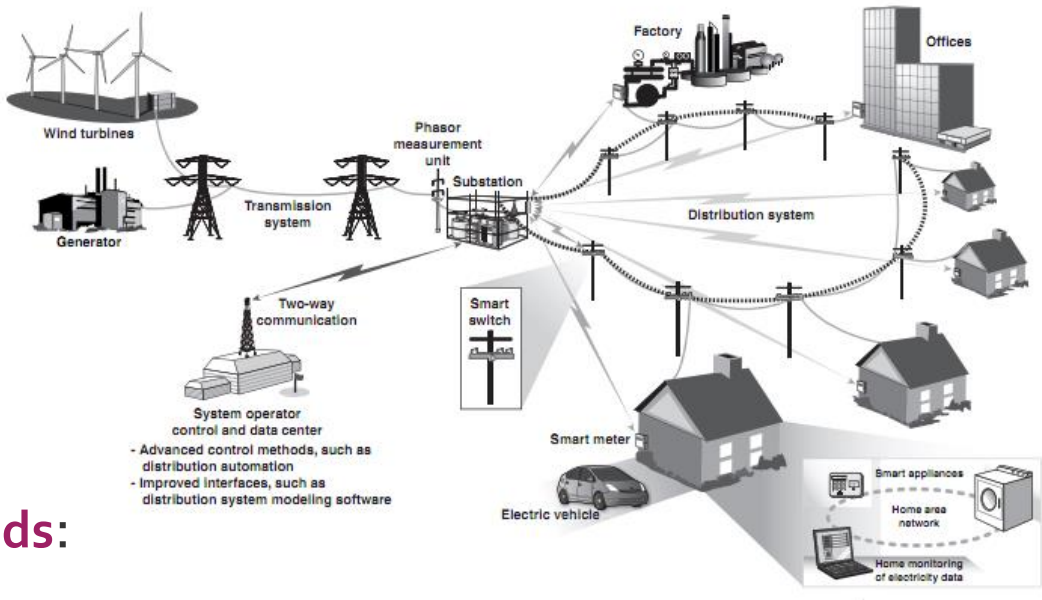
Smart Grid

- **Smart grid** is an electricity network that employs innovative products and services together with intelligent monitoring, control, communication and self-healing technologies.

- Challenges of **legacy power grids**:
  - Uninterrupted power supply
  - Distributed energy resources (DER)
  - Load management
  - New types of electrical devices



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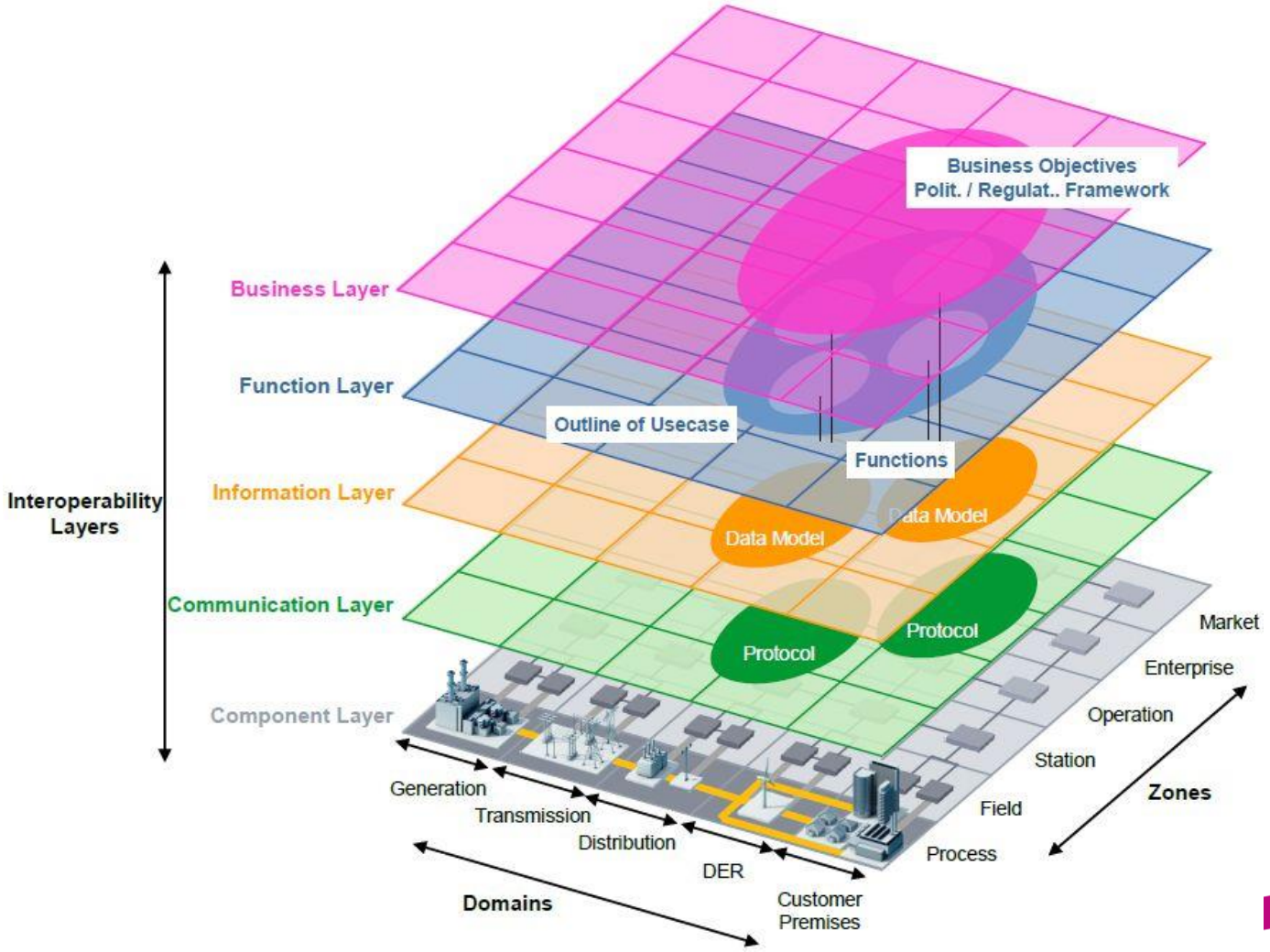
Smart Grid Reference Architecture



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Smart Grid Reliability

- Power (smart) grid is considered a **critical infrastructure**
  - High requirements for reliability
  - Close relation to security, adequacy, availability, survivability and resilience
- Understanding of reliability varies between grid layers
  - **Communication**
    - fraction of time a service is available, fraction of successfully delivered packets, packet delivery latency,…
  - **Distribution**
    - SAIFI, SAIDI, CAIDI, …
- **Loss of load** probability

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Existing Approaches

- Reliability engineering
  1. Reducing the likelihood or frequency of the failure.
  2. Identification and correction of the causes of the failures
  3. Dealing with occurred failures
  4. **Estimating the likely reliability of new designs and analysis of reliability data**
- Most of the reliability-related effort focus on
  - Fault-tolerance, fault-prevention and failure-recovery
- Reliability estimation methods for (smart) power grids consider **physical layer only**.
  - Probability of blackouts
  - HW and communication links failures
  - Missing evaluation of failures in software components.

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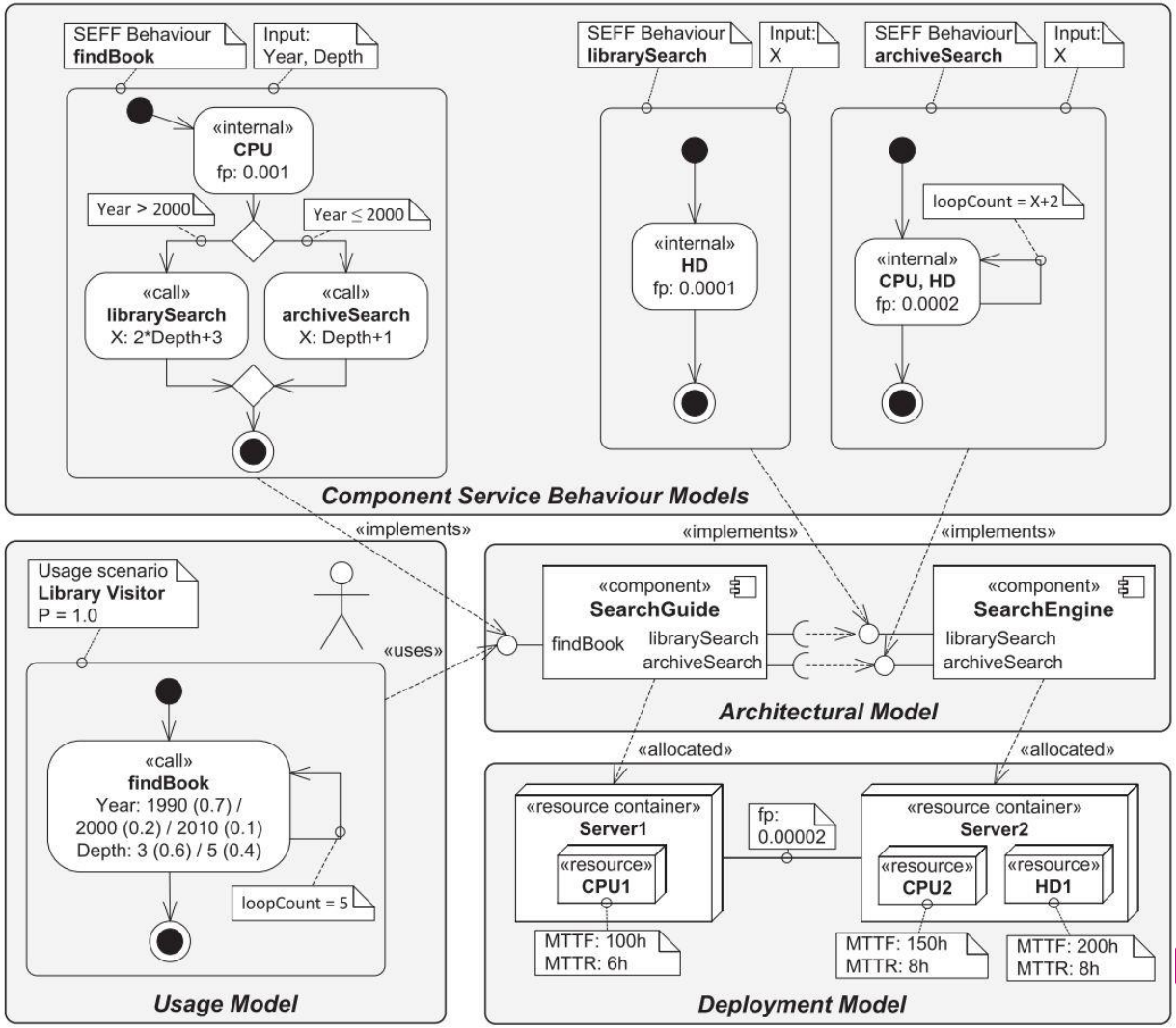
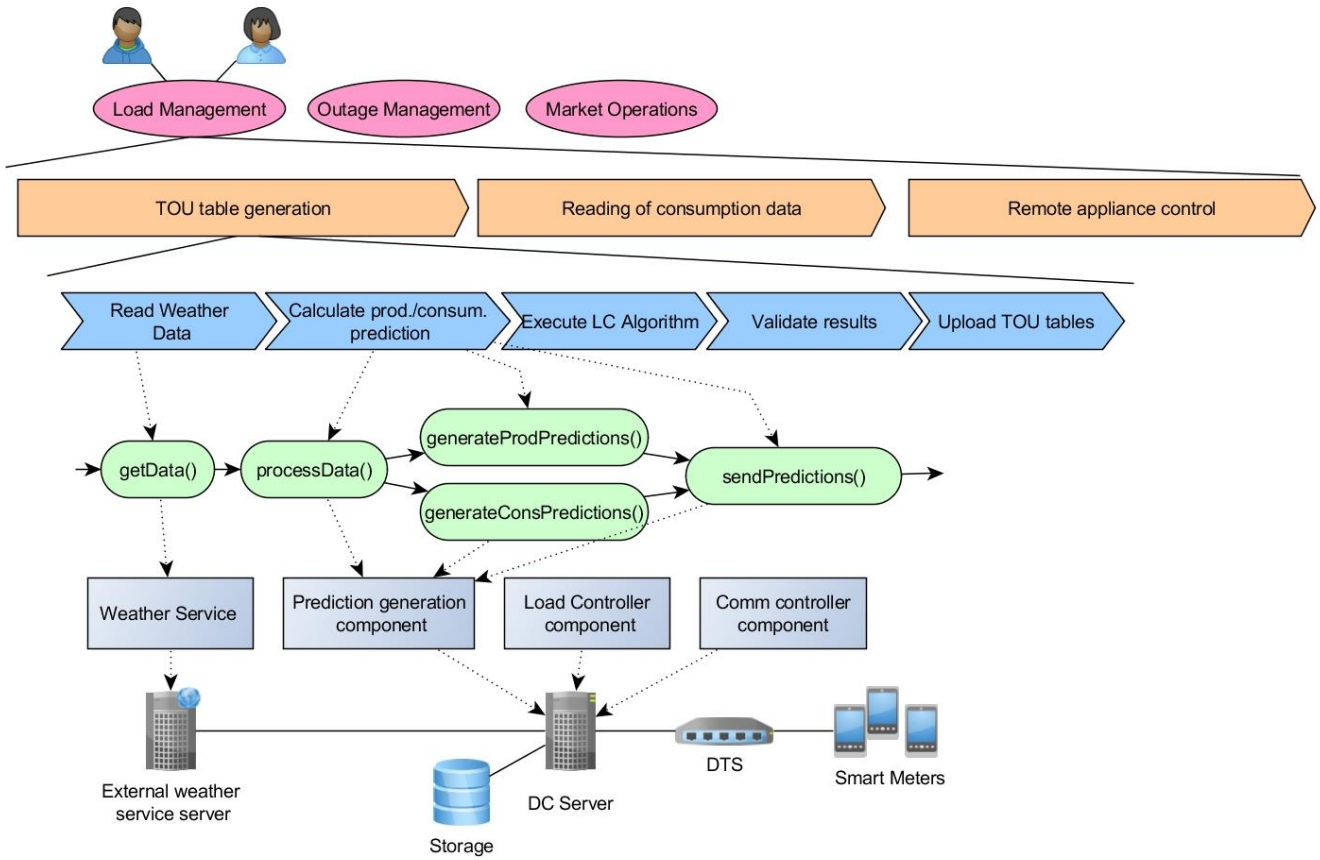
Software Reliability – Palladio Model



Aims of the Thesis

- **Multi-layered** approach for the reliability analysis of a smart grid infrastructure.



Approach Requirements

- In order to address the shortcomings of existing software and power grid reliability analysis, our approach should meet the following **requirements**:
  - **Multi-layered** architecture and analysis
  - **State-based** formal analysis method
  - **Scenario-based**
  - **Hierarchical** decomposition of components
  - Integration of **severities** for failure types
  - Enhanced reference model with additional **artifacts** and **parameters.**
  - Representation of **uncertainity**

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Research Questions

1. What are the **most useful formal methods** for reliability analysis on smart grid scale?
2. What are the **critical parameters and components** in the reliability analysis of smart grid?
3. What is the effect of **uncertainty propagation** from the input data to the method outputs based on the input data representation?
4. What information should be available in the smart grid event logs so that they can be used for automated **identification of failure types and points of failure**?

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Deliverables

1. Smart grid reliability analysis approach
   - **Parametrized reference model** capturing the mapping between the layers of the smart grid infrastructure.
   - **Analysis method** that transforms the reference method into a formal representation and derives the reliability outputs.
   - **Tool** implementing the reference model and analysis method.
2. Method for **extracting failure types and points of failure** from the event logs collected from smart meters and other smart grid components.
3. **Taxonomy** of failure and fault types in smart grids

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Methods and Approach

- Exploration of smart grid domain, **survey of smart grid deployment** projects.
- **Review of formal methods** for reliability analysis
- Extension of **Palladio Component Model**
  - More detailed hardware modelling
  - Hierarchical decomposition
  - Additional annotations and parameters
  - Uncertain parameters
- **Modelling and evaluation** of the proposed solutions
- **Validation** of the approach – simulation and sensitivity analysis
  - Feasibility of modeling abstraction
  - Feasibility of estimation of model annotations
  - Validity of formal model selection
  - Significance and robustness of prediction results
- Iterative **refinement**

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Time Plan

- **Spring 2017**
  - Thesis proposal defence
  - Continuation of our previous work of anomaly
  - Analysis of Palladio for possibilities of plugin extensions
  - Evaluation formal models
- **Fall 2017**
  - Construction of the reference model
  - Extension of the hardware modeling capabilities of the Palladio tool
  - Publication of the detection of the smart grid failure types
  - Publication of the taxonomy of failure and fault types in smart grids

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Time Plan

- **Spring 2018**
  - Implementation of the hierarchical decomposition
  - Implementation of the uncertainty representation
  - Publication of the conceptual meta-model.
  - Evaluation of the model on the case study
  - Doctoral thesis preparation
- **Fall 2018**
  - Doctoral thesis submission
  - Publication of the reliability model, including the tool and evaluation of a case study.

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Achieved Results - Publications

- **Detection of anomalies in Smart grid network**
  - Bruno ROSSI, Stanislav CHREN, Barbora BÜHNOVÁ and Tomáš PITNER. *Anomaly Detection in Smart Grid Data: An Experience Report.* In The 2016 IEEE International Conference on Systems, Man, and Cybernetics (SMC 2016). IEEE, 2016. 6pp.
- **Local load optimization**
  - Stanislav CHREN and Barbora BÜHNOVÁ. *Local Load Optimization in Smart Grids with Bayesian Networks*. In The 2016 IEEE International Conference on Systems, Man, and Cybernetics (SMC 2016). : IEEE, 2016. 7 pp.

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Achieved Results - Publications

- **Smart grid technologies and architectures**
  - Stanislav CHREN, Bruno ROSSI and Tomáš PITNER. *Smart grids deployments within EU projects: The role of smart meters.* In 2016 Smart Cities Symposium Prague (SCSP). IEEE, 2016, 5 pp.
  - Tomáš PITNER, Filip PROCHÁZKA, Bruno ROSSI, Barbora BÜHNOVÁ, Stanislav CHREN, Andrea VAŠEKOVÁ, Jan ROSECKÝ and Václav STUPKA. *Final Report from Preliminary Research for Automated Metering Management)*. ČEZ Distribuce, a.s., 2015. 8 pp.
- **Failure data collection for reliability prediction models**
  - Barbora BÜHNOVÁ, Stanislav CHREN and Lucie KREJČÍŘOVÁ. *Failure Data Collection for Reliability Prediction Models: A Survey*. In the 10th International ACM Sigsoft Conference on Quality of Software Architectures (QoSA'14). ACM, 2014, 10 pp.
- **Reliability in smart cities**
  - CHREN, Stanislav, Barbora BÜHNOVÁ and Bruno ROSSI. *Identification of Reliability Bottlenecks in Smart Cities.* In 42nd Euromicro Conference on Software Engineering and Advanced Applications (SEAA). IEEE, 2016.

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Thank you for your attention.

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