Leipzig University
of Applied Sciences

Hochschule für Technik, Wirtschaft und
Kultur
Leipzig
Fakultät Elektrotechnik und
Informationstechnik

Systems Engineering

Master Course Project Booklet

Smart Grid, E-Mobility, IoT and Energy Management

Course:	Systems Engineering
Degree Program:	Master of Science
Lecturer:	Prof. Dr. Pretschner
Semester:	Winter Semester 2025/26
Version:	1.0
Date:	May 8, 2026

Contents

1 Introduction

This report template defines the structure for project work in the Master course **Systems Engineering**. The projects address complex technical systems from the domains of Smart Grid, E-Mobility, electrical charging infrastructure, IoT, and energy management.

The aim is to apply a model-based systems engineering approach. Students shall not merely describe a technical solution, but build a consistent system model that connects stakeholder needs, requirements, architecture, behavior, quantitative reasoning, and verification.

1.1 Learning Objectives

After completing the project, students should be able to:

- define stakeholder needs and derive system requirements,
- structure a system using SysML-oriented architecture views,
- model behavior, interfaces, and states,
- apply parametric reasoning to energy, power, timing, or performance questions,
- derive verification concepts from requirements and system behavior,
- justify design decisions through trade-off reasoning.

2 General Project Framework

2.1 Expected Deliverables

Each project group shall submit:

1. a written report of approximately 15 - 20 pages,
2. SysML-oriented diagrams,
3. a final presentation of 15 minutes,
4. optional simulation, prototype, or calculation files.

2.2 Required Model Views

Each project shall include at least the following views:

- stakeholder and context analysis, Use Cases
- requirements model,
- system architecture model,
- internal interface model,
- behavioral model,
- parametric or analytical model,
- verification concept.

3 Methodological Approach

3.1 Requirements Engineering

The project shall begin with a clear problem statement and stakeholder analysis. Requirements should be derived from stakeholder needs and organized hierarchically.

Typical requirement categories are:

- functional requirements,
- interface requirements,
- safety and security requirements,
- performance requirements,
- operational and environmental constraints,
- verification requirements.

3.2 System Architecture

The architecture model shall identify the main system elements and their relationships. A block definition view and an internal structure view are expected.

Important questions are:

- What are the major subsystems?
- Which interfaces exist between subsystems?
- Which elements satisfy which requirements?
- Which elements are external actors or neighboring systems?

3.3 Behavioral Modeling

At least one important system behavior shall be modeled, for example:

- charging workflow,
- load management process,
- state machine of an energy management system,
- fault handling scenario,
- communication sequence between backend and device.

3.4 Parametric and Analytical Modeling

The project shall include at least one quantitative relation. Suitable examples include:

- power balance,
- energy storage capacity,
- charging time,
- communication latency,
- load peak reduction,
- cost or efficiency calculation.

4 Project Topics

4.1 Project 1: Intelligent EV Charging Park with Load Management

4.1.1 Motivation

The increasing number of electric vehicles creates new challenges for distribution grids. Charging parks with several high-power chargers may cause load peaks that exceed the available grid connection capacity.

4.1.2 Objective

Design a model-based system architecture for an intelligent EV charging park that includes:

- dynamic load management,
- integration of photovoltaic generation,
- optional stationary battery storage,
- prioritization of charging processes,
- interface to a backend or operator platform.

4.1.3 Expected Modeling Focus

- requirement model for grid limits, charging time, availability, and safety,
- block definition diagram for grid connection, chargers, EMS, PV, battery, and backend,
- internal block diagram for energy and information flows,
- activity diagram for charging process control,
- parametric model for power balance.

4.1.4 Example Parametric Relation

$$P_{\text{grid}} + P_{\text{PV}} + P_{\text{battery}} = \sum_{i=1}^{n} P_{\text{charger},i}$$

4.2 Project 2: IoT-Based Energy Management System for an Industrial Site

4.2.1 Motivation

Industrial sites increasingly combine flexible loads, local generation, storage systems, and digital monitoring. An IoT-based energy management system can help reduce peak loads and optimize energy usage.

4.2.2 Objective

Design a distributed energy management architecture that integrates sensors, actuators, controllers, and a central or edge-based optimization layer.

4.2.3 Expected Modeling Focus

- stakeholder analysis for operator, facility manager, grid operator, and maintenance staff,

- requirements for monitoring, control, scalability, security, and availability,
- architecture model for IoT devices, gateway, EMS platform, and controlled loads,
- behavioral model for load shifting or peak shaving,
- verification concept for communication reliability and control response.

4.3 Project 3: Bidirectional Charging Infrastructure for Vehicle-to-Grid

4.3.1 Motivation

Bidirectional charging enables electric vehicles to act as distributed energy storage. This creates opportunities for peak shaving, local flexibility, and grid services, but also introduces technical, economic, and safety challenges.

4.3.2 Objective

Develop a model-based system concept for a bidirectional charging infrastructure that supports controlled energy flow between vehicle, charging station, backend, and grid.

4.3.3 Expected Modeling Focus

- requirements for bidirectional power flow, user authorization, and battery protection,
- interface model between vehicle, charger, EMS, and grid operator,
- state machine for charging, discharging, standby, and fault states,
- parametric model for energy transfer and battery impact,
- trade-off analysis between grid benefit and battery degradation.

4.4 Project 4: Digital Twin for a Smart Grid Subsystem

4.4.1 Motivation

Digital twins can support monitoring, prediction, and decision-making in smart grids. They combine physical system models, operational data, and simulation or analytics.

4.4.2 Objective

Design a digital twin concept for a grid subsystem with distributed generation and variable loads.

4.4.3 Expected Modeling Focus

- system boundary between real grid, data acquisition, simulation model, and operator interface,
- requirements for data quality, update rate, prediction horizon, and model validity,
- architecture model for sensors, communication, digital twin platform, and visualization,
- behavior model for data update and prediction workflow,
- verification concept for model accuracy and operational usefulness.

4.5 Project 5: Secure Communication Architecture for Charging Infrastructure

4.5.1 Motivation

Public and semi-public charging infrastructure is part of a critical energy and mobility ecosystem. Secure communication is necessary to prevent misuse, manipulation, and operational disruption.

4.5.2 Objective

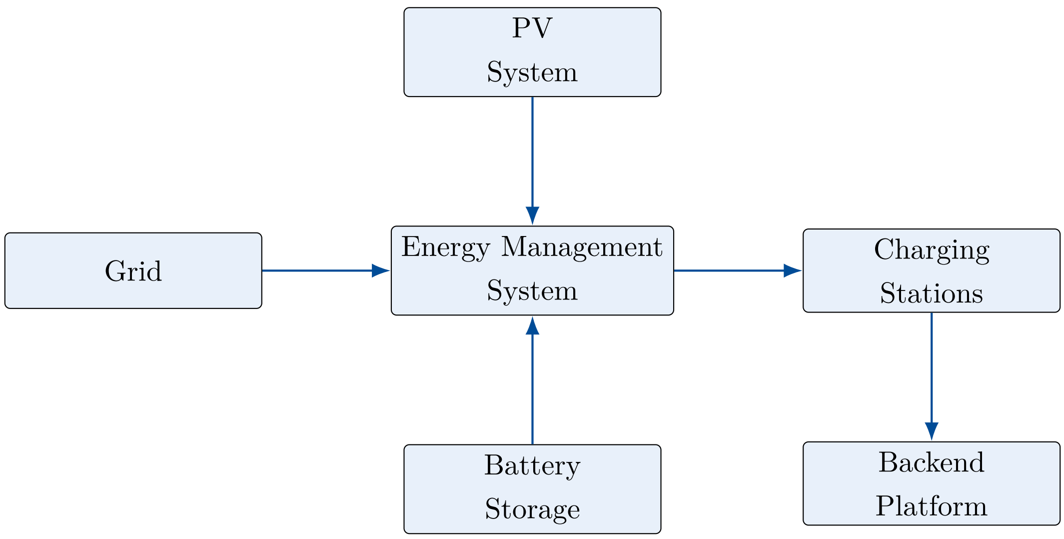
Develop a secure system and communication architecture for networked charging infrastructure.

4.5.3 Expected Modeling Focus

- threat-oriented requirement analysis,
- architecture model for charger, vehicle, backend, user authentication, and operator system,
- communication sequence for authentication and charging authorization,
- state model for normal operation, communication failure, and security incident,
- verification concept for security requirements.

5 Example SysML-Oriented Diagram Templates

5.1 Example Architecture Diagram



5.2 Example Requirement Node

«requirement»
REQ-EMS-01 Load Limit
The charging park shall not exceed the configured grid connection limit.
system-level requirement

6 Evaluation Criteria

Criterion	Description	Weight
Requirements	Quality, clarity, structure, and testability of requirements	20%
Architecture	Consistency, completeness, and interface clarity	25%
Behavior and states	Meaningful modeling of workflows, sequences, or state logic	15%
Parametric analysis	Quantitative reasoning and interpretation of results	15%
Verification	Traceable verification concept and test logic	10%
Presentation	Clarity, argumentation, and professional communication	10%
Innovation	Creativity, depth, and engineering maturity	5%

7 Report Structure

The final report should follow this structure:

1. Introduction and motivation
2. Problem statement and system boundary
3. Stakeholder analysis
4. Requirements
5. System architecture
6. Interfaces and internal structure
7. Behavior and state logic
8. Parametric model or analysis
9. Verification concept
10. Trade-off discussion
11. Conclusion and outlook

8 Submission

The final submission shall include:

(1) PDF report written in LaTex, (2) eventually model files and/ or diagram source files, (3) presentation slides, (4) eventually optional simulation and/ or prototype files.

9 Final Remarks

The project is intended to demonstrate model-centered systems engineering thinking. The quality of the project is not measured by the number of diagrams alone, but by the consistency and engineering usefulness of the model. A strong project connects requirements, architecture, behavior, quantitative reasoning, trade-offs, and verification into a coherent argument.