

# **Mains Operation by Using Learning Mechanisms in a Semi- Decentralized Control Architecture**

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# Background and statutory framework

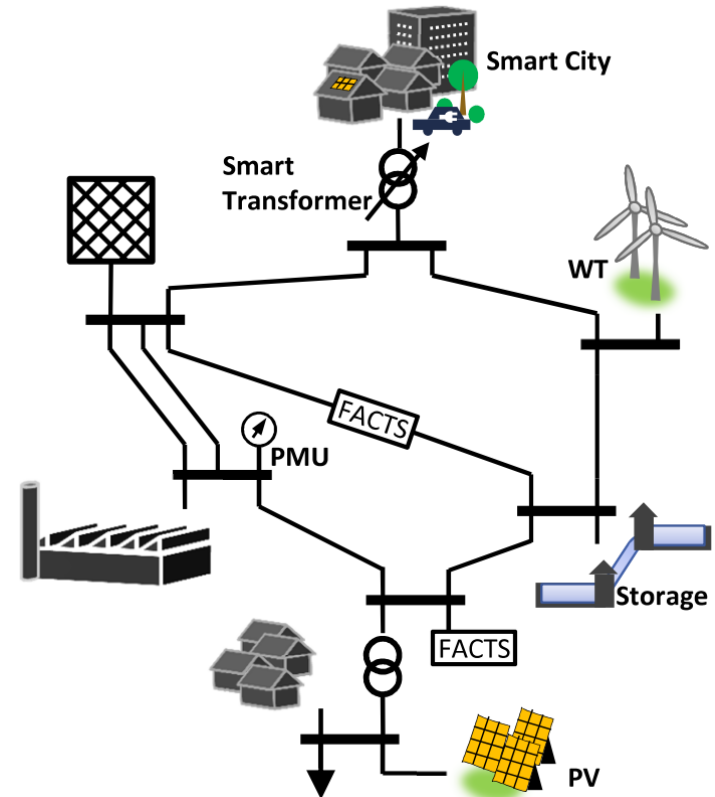
- German „Energiewende“
  - European Union: 20-20-20-Targets
  - 35% electricity generation from renewable Energies in Germany by 2020
  - Nuclear phaseout until 2022

## Agenda

- Future Distribution Grid
- Control Approach
  - Generic System
  - Control System
- Optimization System

# Future Distribution Grid

- New Technology
    - Renewable Energies
    - Storages
    - Electric Vehicles ( $10^6$  in 2020)
    - Demand Response
    - Intelligent mains utility equipment
  - Consequences
    - Increasing number of influences
    - Decentralization
    - Volatility in demand and supply
- Complexity

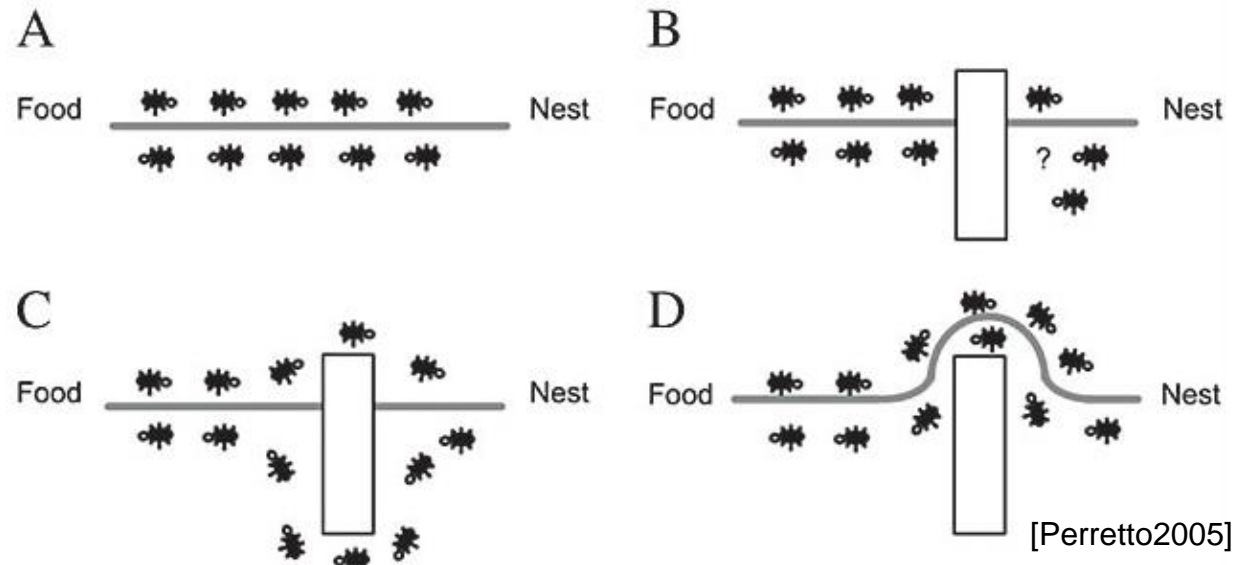


# Dealing with Complexity

- Organic Computing
  - Design paradigm for self-organizing systems
  - Achieving a lifelike („organic“) behavior
  - Requirements: self-\*-properties
    - self-healing, self-adapting, self-optimizing, self-configuring

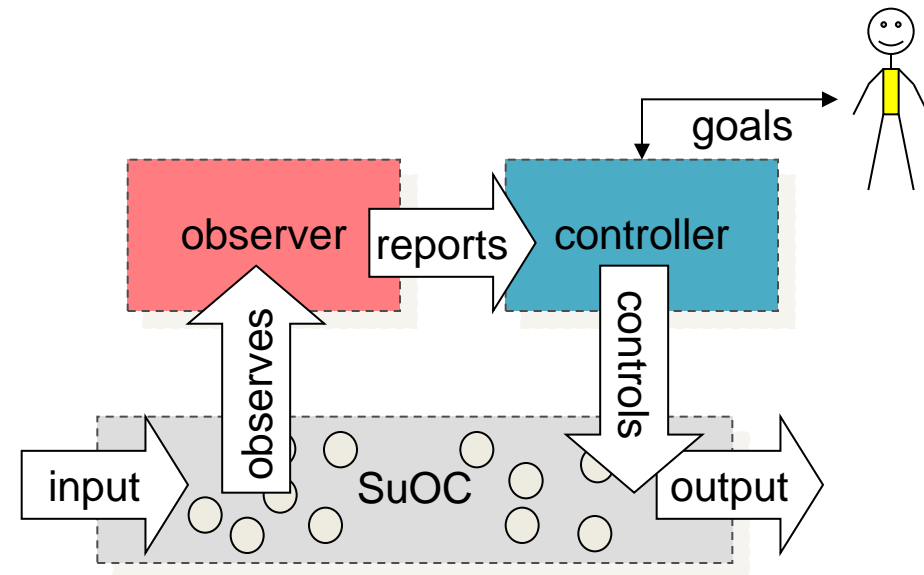
- Example – Ants

- Searching for food
- Pheromones
- Emergence (Stigmergy)

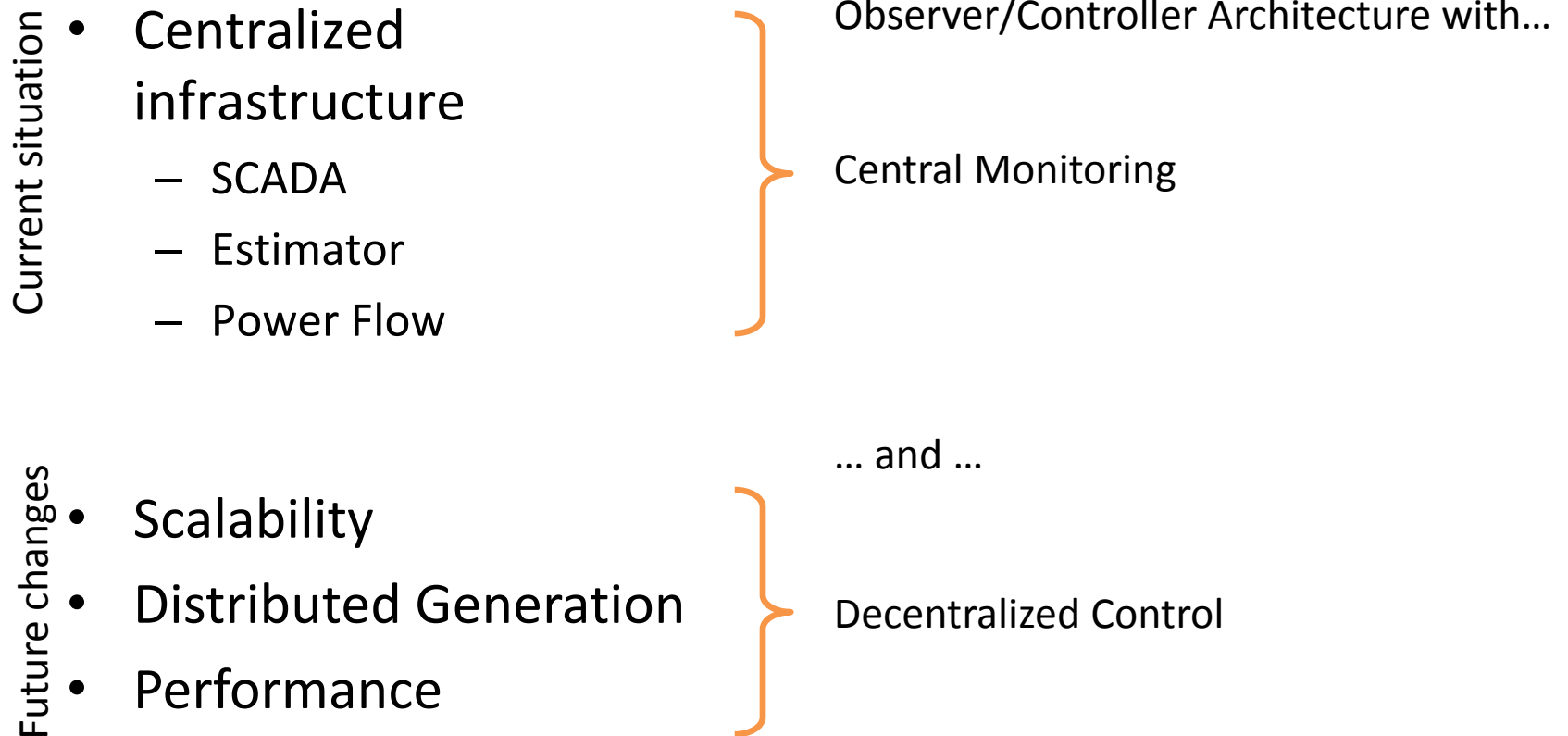


# Generic Observer/Controller-Architecture

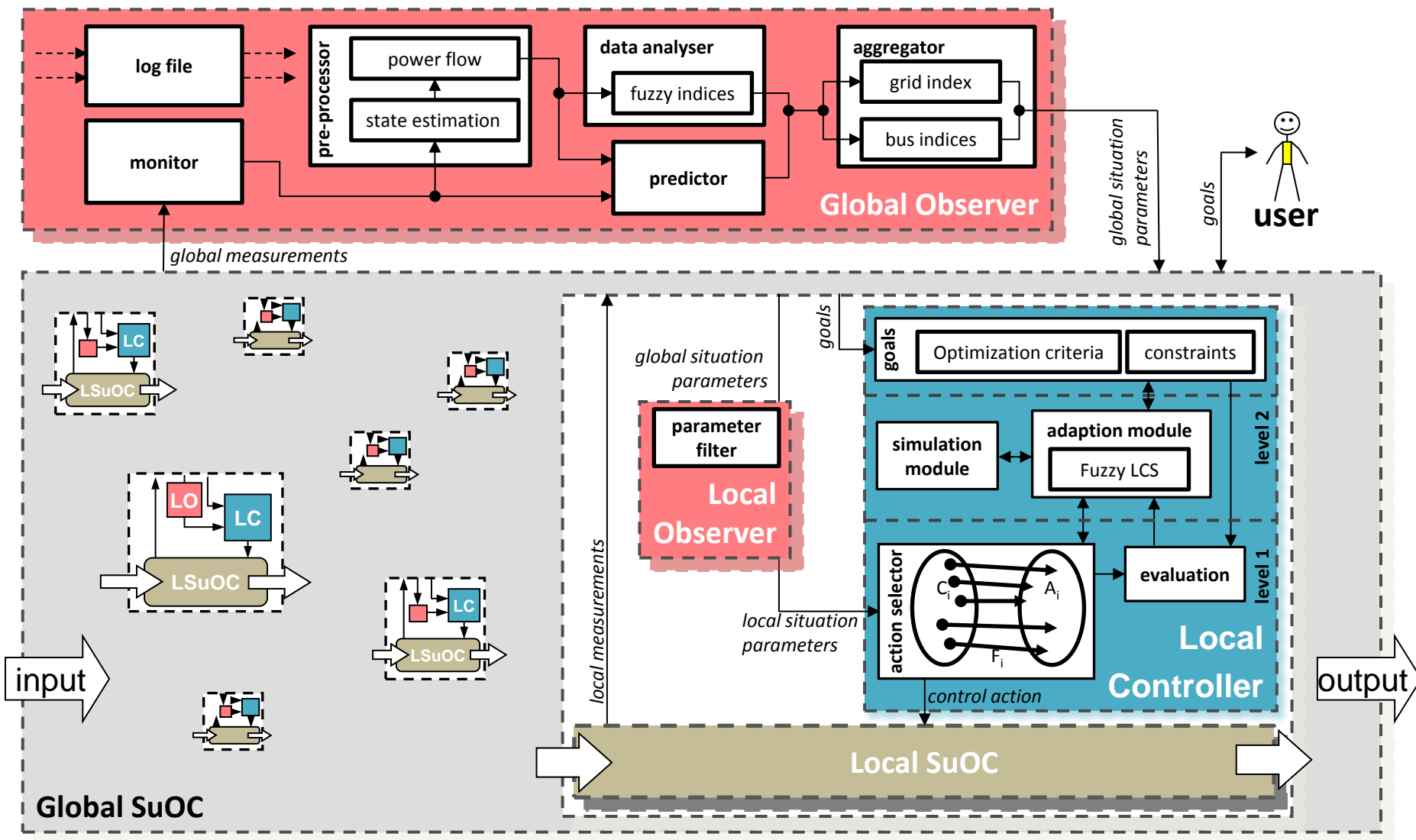
- System under Observation and Control (SuOC)
  - Interacting entities
  - System states
- User
  - Defines system goals
- Observer
  - Characterize the SuOC
- Controller
  - Influences the SuoC
- Closed control loop
  - Similarities to model predictive control



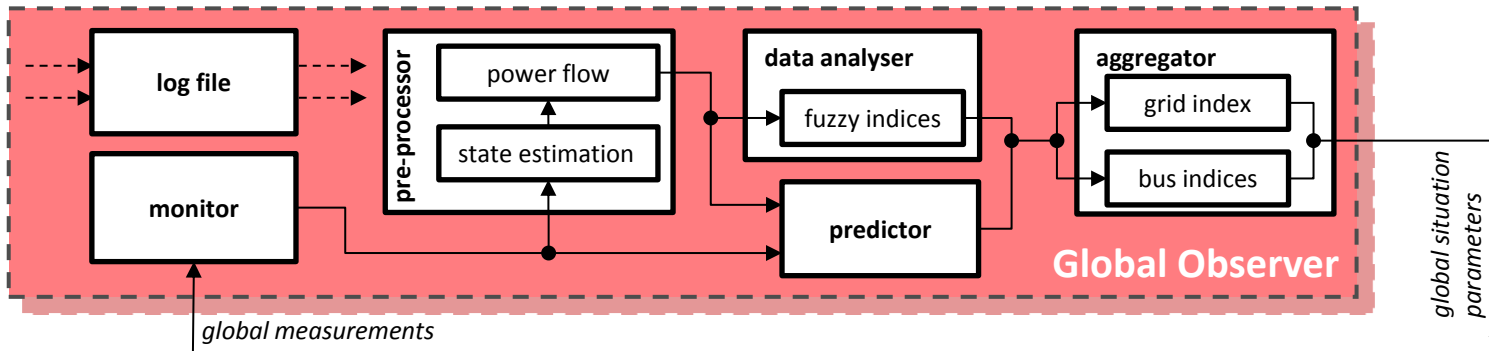
# Adaption to Power System



# Semi-Distributed Observer/Controller Architecture



# Global Observer



- Global measurements:
    - PMU, Smart Meter, Injections, ...
  - Monitor: Data preparation
  - Pre-processor:
    - State Estimation, Power Flow
  - Data Analyzer: Data mining
    - Fuzzy States
  - Predictor
  - Aggregator:
    - Global Situation Parameter
  - Fuzzy logic
    - Extension of boolean logic to membership values  $\mu \in [0,1]$
    - Easy way to express human thinking:
      - „The line between is **slowly starting** to be overloaded.“
- $\rightarrow \mu_{Overload} = 0,25$

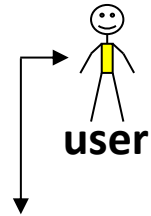


# User and goals

- User
  - Grid Operator
  - No focus on business case
- Goals
  - Minimization of power losses
  - Minimization of voltage deviations
  - Minimization of reactive power injections

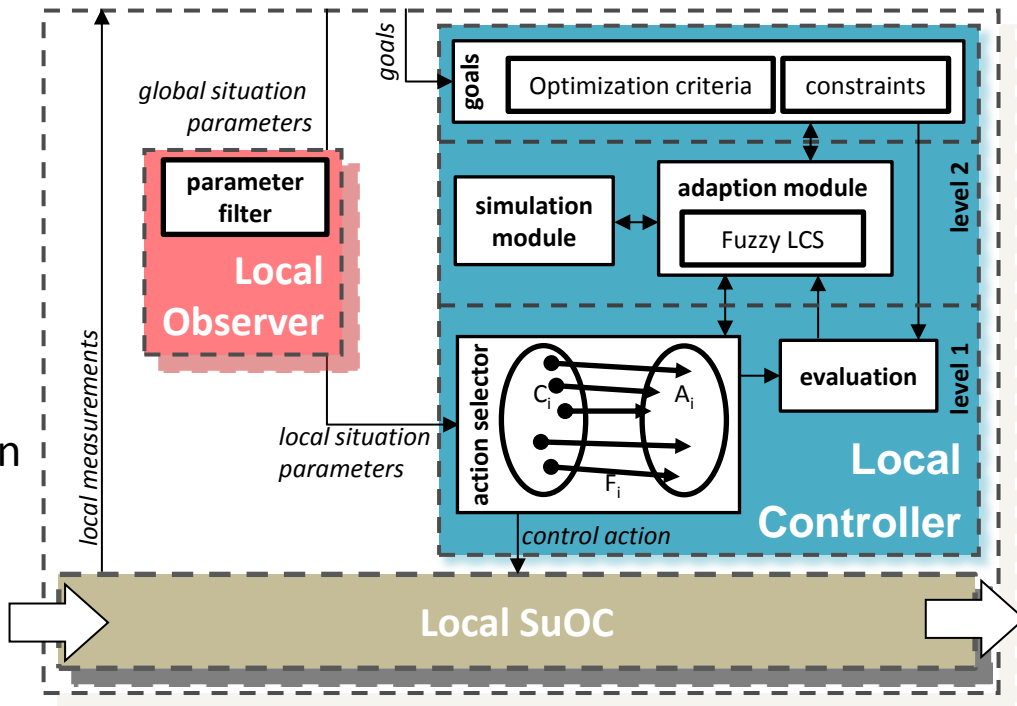
Technical goals that can be seen as representation for costs

Multi-criteria optimization problem



# Local Controller

- Local SuOC
  - Controllable Subsystem
- Local Observer
- Local Controller
  - 2 level learning
  - Driven by optimization criteria & constraints
  - Control action via a mapping
  - Performance evaluation
  - Learning environment for adaption
  - Simulation module for offline learning



# Optimization: Fuzzy Learning Classifier

- Learning adequate behavior
- Behavior is expressed by fuzzy rules
  - Fixed structure
  - Dimensions depend on local facilities and given input values
- Learning via a genetic algorithm
  - Binary rule encoding
  - Evaluation
  - Selection
  - Recombination
  - Mutation
  - Stop criterion



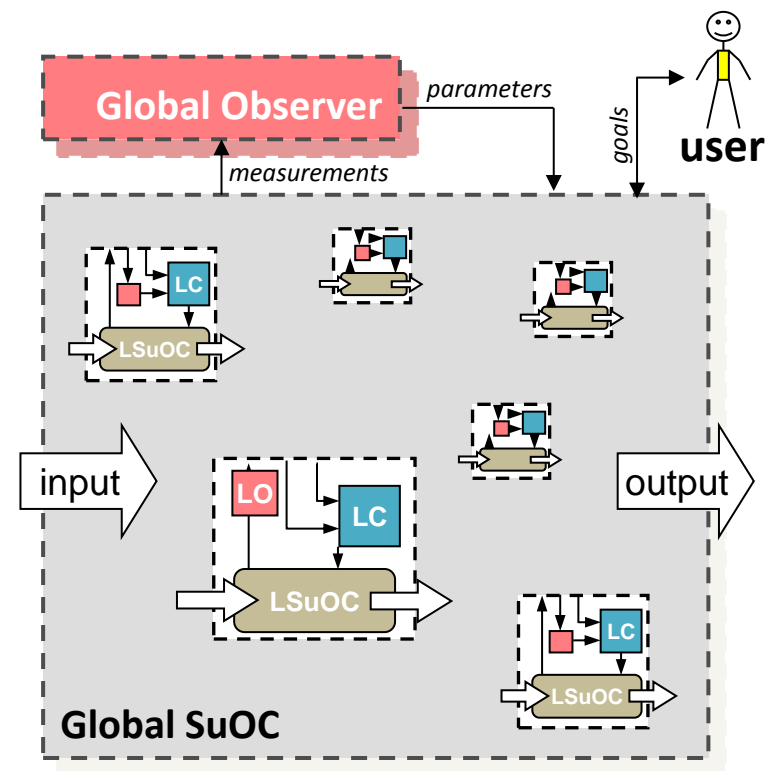
*If the voltage at bus1 is very high, **then** set the injection of PV1 to low.*

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# Mains Operation by Using Learning Mechanisms in a Semi- Decentralized Control Architecture

- Energiewende
- Organic Computing
  - Complexity handling
  - Self-organization
- Decentralization
  - Scalability
  - Extension
- FLCS
  - Situation adaptivity
  - Computing time



# References

- [Richter2009] „Controlled self-organisation using learning classifier systems”, Dissertation Karlsruhe Institute of Technology (KIT), KIT Scientific Publishing, 2009.
- [Perretto2005] „Reconstruction of phylogenetic trees using the ant colony optimization paradigm”, Genet. Mol. Res. 4 (3): 581-589 (2005).