OpenEMS

Conference 2024

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OpenEMS

OpenEMS Conference 2024

OpenEMS Energy Scheduler & Genetic Algorithms

29th November 2024

01

More of a technical derivation of the current situation, challenges, and implementation...

Powermanagement vs. Energymanagement

- State-of-the-Art
  - (Nearly) nobody really does Energymanagement but only Power-/Relaymanagement
  - Even OpenEMS Controllers are mostly optimized for „Single-Objective Optimization“
    - e.g. Self-consumption optimization with Battery, Electric Vehicle PV surplus charging, threshold based relay switching

- Multi-Use Applications are hardly possible with thresholds. Example:
  - Optimization of
    - When to charge/discharge a local battery?
    - When to charge (or discharge) an electric vehicle?
    - When should a heat pump or electric heater run?
    - …

Multi-Objective Optimization

Modeling an energy system as mathematical formula

Power balance equation:

$$\text{p.grid.power} = \text{p.hh.power.cons} - \text{p.pv.power.prod} - \text{p.ess.power}.$$

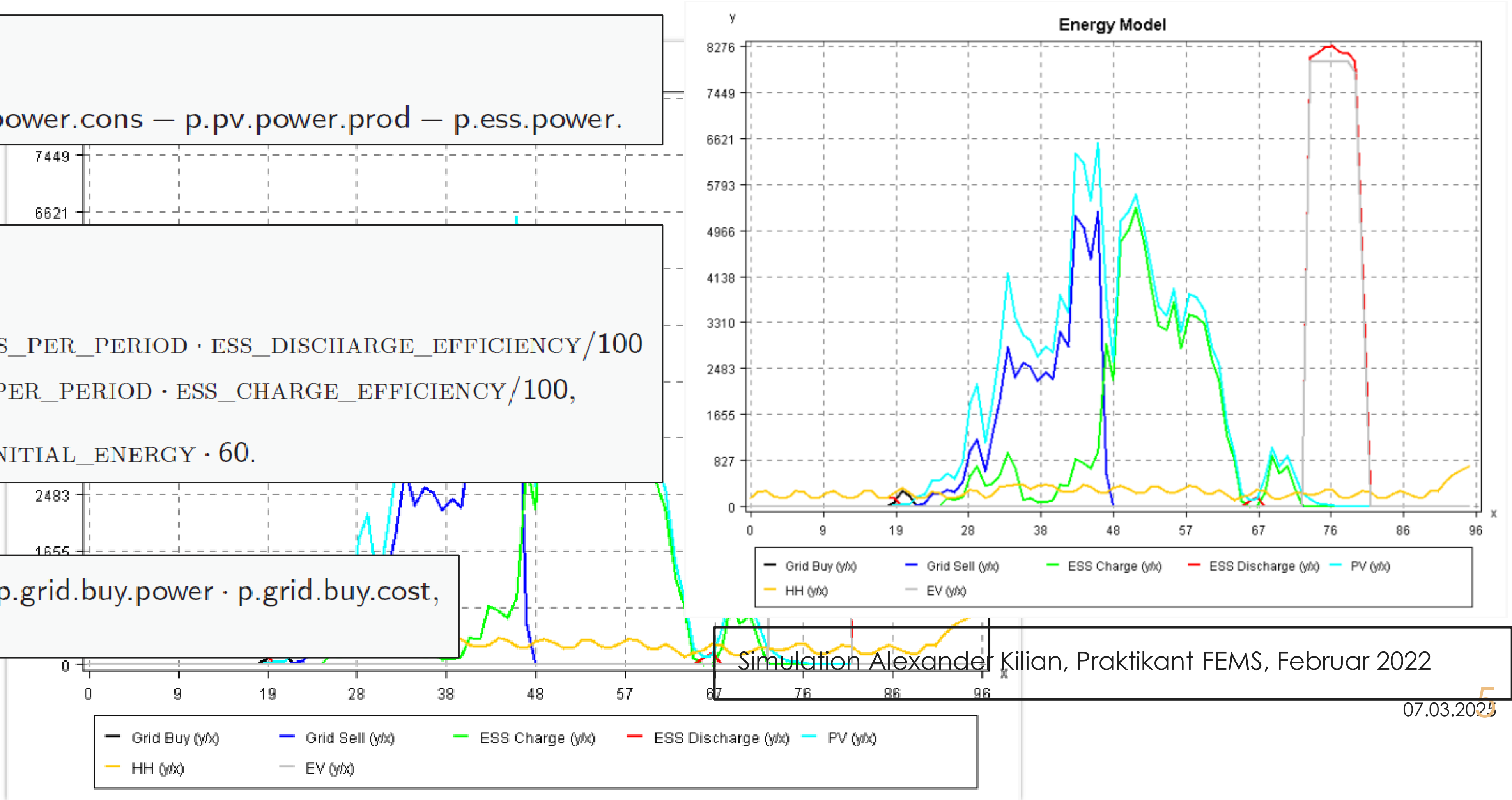
with constraints

$$\begin{aligned} &\text{p.ess.energy} \\ &= \text{periods[i-1].ess.energy} \\ &- \text{p.ess.discharge.power} \cdot \text{MINUTES\_PER\_PERIOD} \cdot \text{ESS\_DISCHARGE\_EFFICIENCY}/100 \\ &+ \text{p.ess.charge.power} \cdot \text{MINUTES\_PER\_PERIOD} \cdot \text{ESS\_CHARGE\_EFFICIENCY}/100, \end{aligned}$$

where $\text{periods[0].ess.energy} = \text{ESS\_INITIAL\_ENERGY} \cdot 60.$

and a target function

$$\text{gridBuyCostSum} = \sum_{\text{p} \in \text{em.periods}} \text{p.grid.buy.power} \cdot \text{p.grid.buy.cost},$$



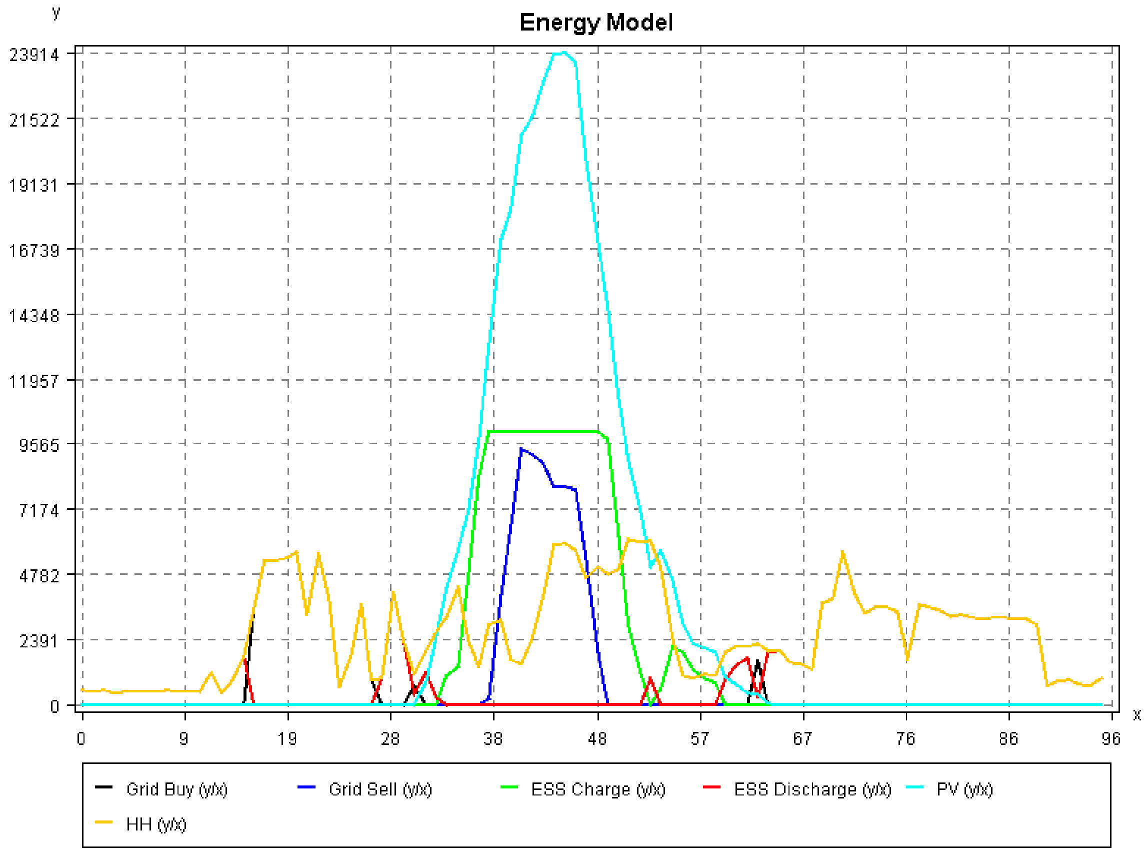
Simulation Alexander Kilian, Praktikant FEMS, Februar 2022

Mathematical optimization: Practical problems

- Alternative: Linear Equation System
  - Very fast – but works only for linear, steady constraints
  - Example: EV charging requiring interval]0;6[A is not possible = not steady
- Alternative : Mixed Integer Linear Programming (MILP)
  - Complex in calculation; not applicable for real-time control
  - Example: 10,000 W power; 96 periods (= 24 x 15 min.) => solution space 96^10,000
  - Not solvable purely mathematically -> 'branch and bound' -> 'structured trial and error'
  - Licenses for programming libraries are not compatible with the OpenEMS open-source license or are very expensive. Cannot run locally on IoT device.
- Every algorithm must be developed twice:
  - as real-time control in Java code
  - as a mathematical formula"

Mathematical optimization: Problems part 2: even if…

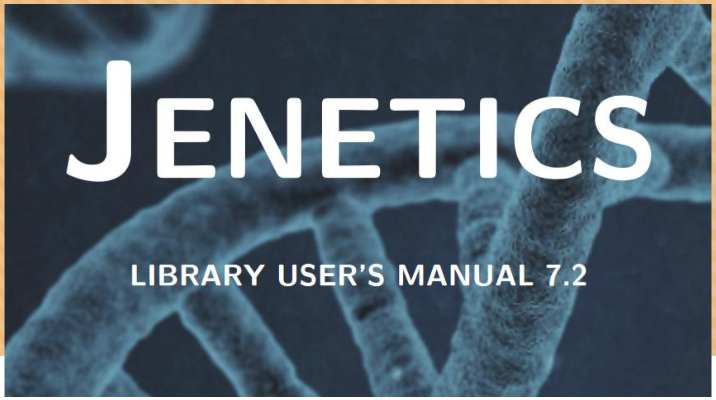
- Input variables
  - PV generation: 1,234 W / 15 min
  - Consumption: 234 W / 15 min
- Result of a mathematical optimization
  - Charge battery with 1,000 W / 15 min
- NO!
  - What does this result actually mean?
  - Perform balancing at the grid connection point.



The idea: do not optimize the power but the operating mode

- MILP (Mixed Integer Linear Programming)
  - Solution space: 96^10,000 (but not every "1 W" variation is actually meaningful)
- Operating modes
  - Are already smart (e.g., self-consumption optimization, surplus charging, etc.)
  - A few operating modes are sufficient, e.g., dynamic electricity tariff for storage:
    Self-consumption optimization - Delayed discharge - Charging from the grid
    Solution space: 96^3 (= 884,736)
  - Implementable in "normal" Java code
- But
  - Still too many possible combinations for brute force
- Solution approach
  - **"Structured trial and error until the best energy plan is found within a limited time frame"**

Genetic Algorithms



JENETICS

LIBRARY USER'S MANUAL 7.2

In computer science and operations research, a genetic algorithm (GA) is a **metaheuristic** inspired by the process of **natural selection** that belongs to the larger class of evolutionary algorithms (EA).

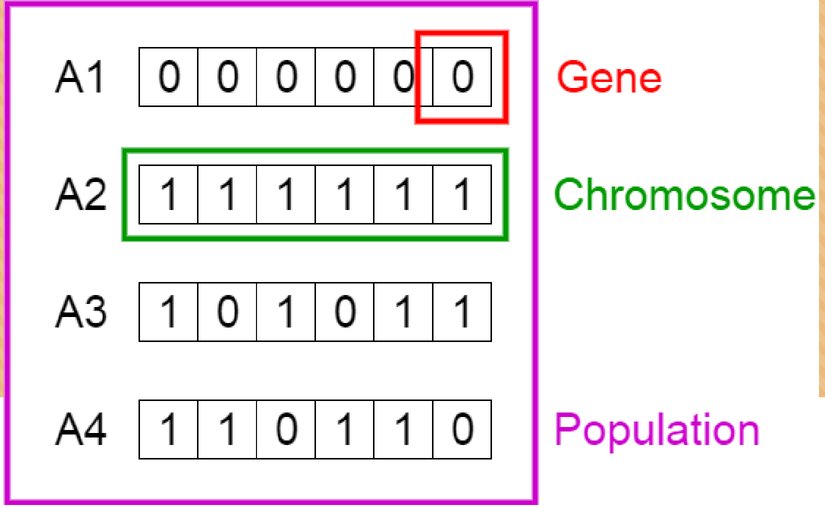
Genetic algorithms are commonly used to generate high-quality solutions to **optimization and search problems** via **biologically inspired operators** such as selection, crossover, and mutation.

Some examples of GA applications include optimizing decision trees for better performance, solving sudoku puzzles, hyperparameter optimization, and causal inference.

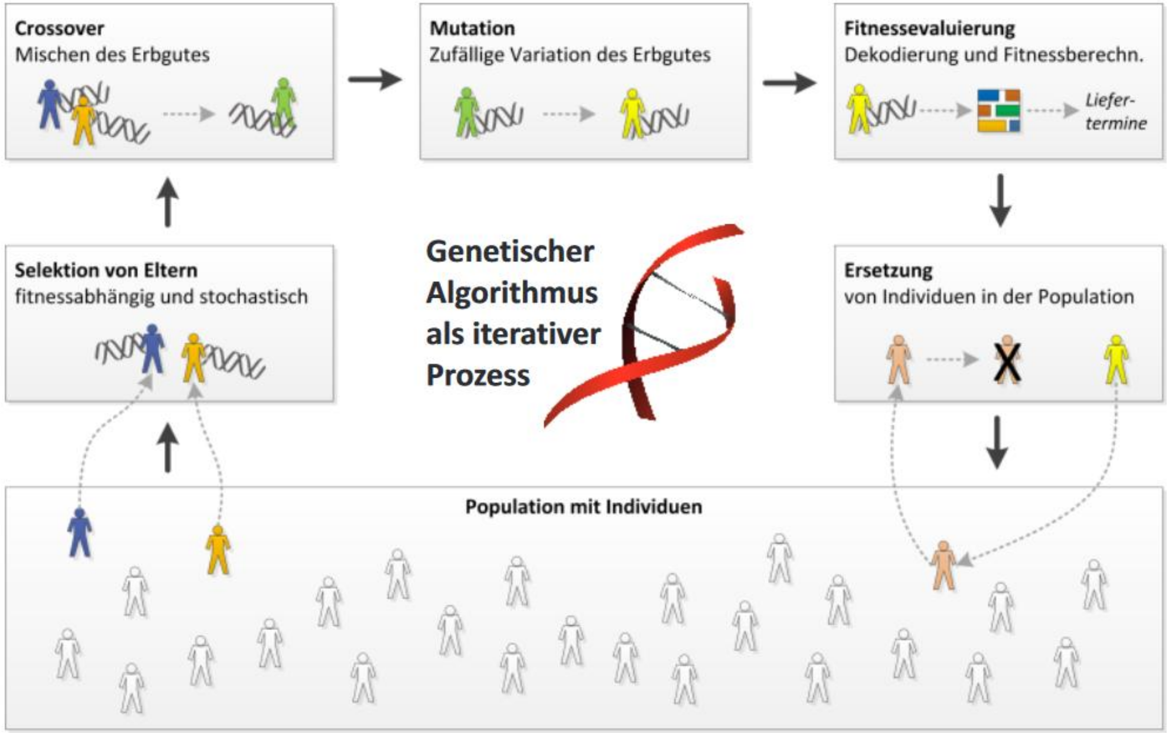
(Wikipedia)

Genetic Algorithms in OpenEMS

- Gene
  = Operation Mode of a Controllers in a 15 min Period
- Chromosome
  = Energy schedule
- Population
  = Multiple different energy schedules that are being simulated
- Cost function
  = Calculates (virtual) costs of the energy schedule



A1	0	0	0	0	0	0
A2	1	1	1	1	1	1
A3	1	0	1	0	1	1
A4	1	1	0	1	1	0

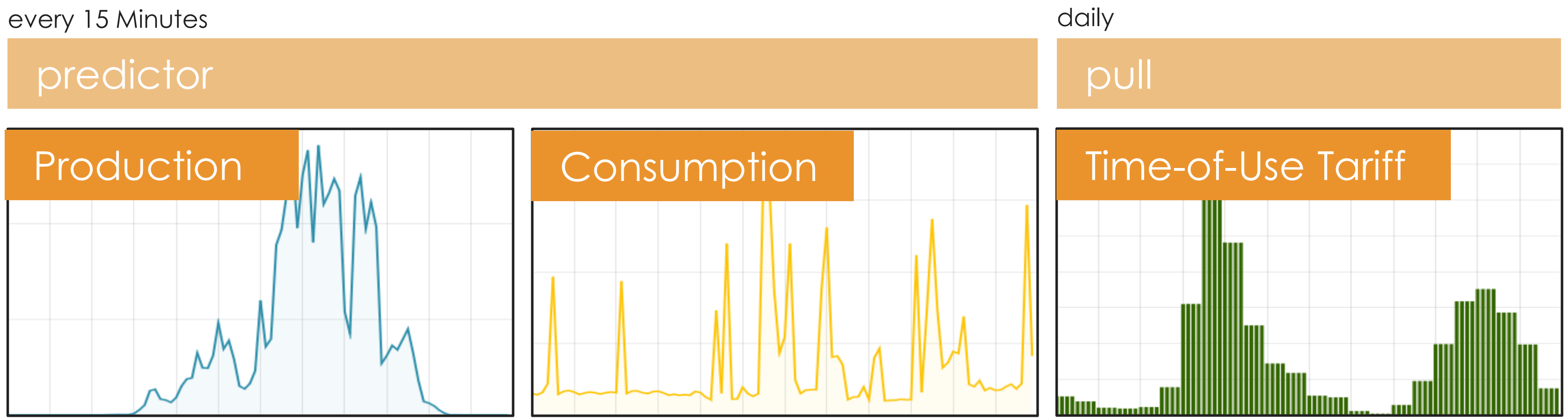


Crossover
Mischen des Erbgutes
Mutation
Zufällige Variation des Erbgutes
Fitnessevaluierung
Dekodierung und Fitnessberechn.
Liefer-
termine
Selektion von Eltern
fitnessabhängig und stochastisch
Genetischer
Algorithmus
als iterativer
Prozess
Ersetzung
von Individuen in der Population
X
Population mit Individuen

https://www.tu-chemnitz.de/wirtschaft/bwl7/optsys/framework/Brosch%C3%BCre.pdf

Genetic Algorithms

t+1	t+2	t+2	t+3	t+4	t+5	…	Cost
Balance	Delay	Balance	Delay	Charge	Charge		2146
🟦	🟦	🟦	🟩	🟩	🟧		1816
🟦	🟦	🟦	🟦	🟦	🟦		**1569**
🟧	🟦	🟩	🟦	🟩	🟩		
🟧	🟩	🟦	🟩	🟦	🟩		
🟧	🟦	🟩	🟧	🟩	🟧		
🟧	🟩	🟩	🟦	🟧	🟧		



every 15 Minutes

predictor

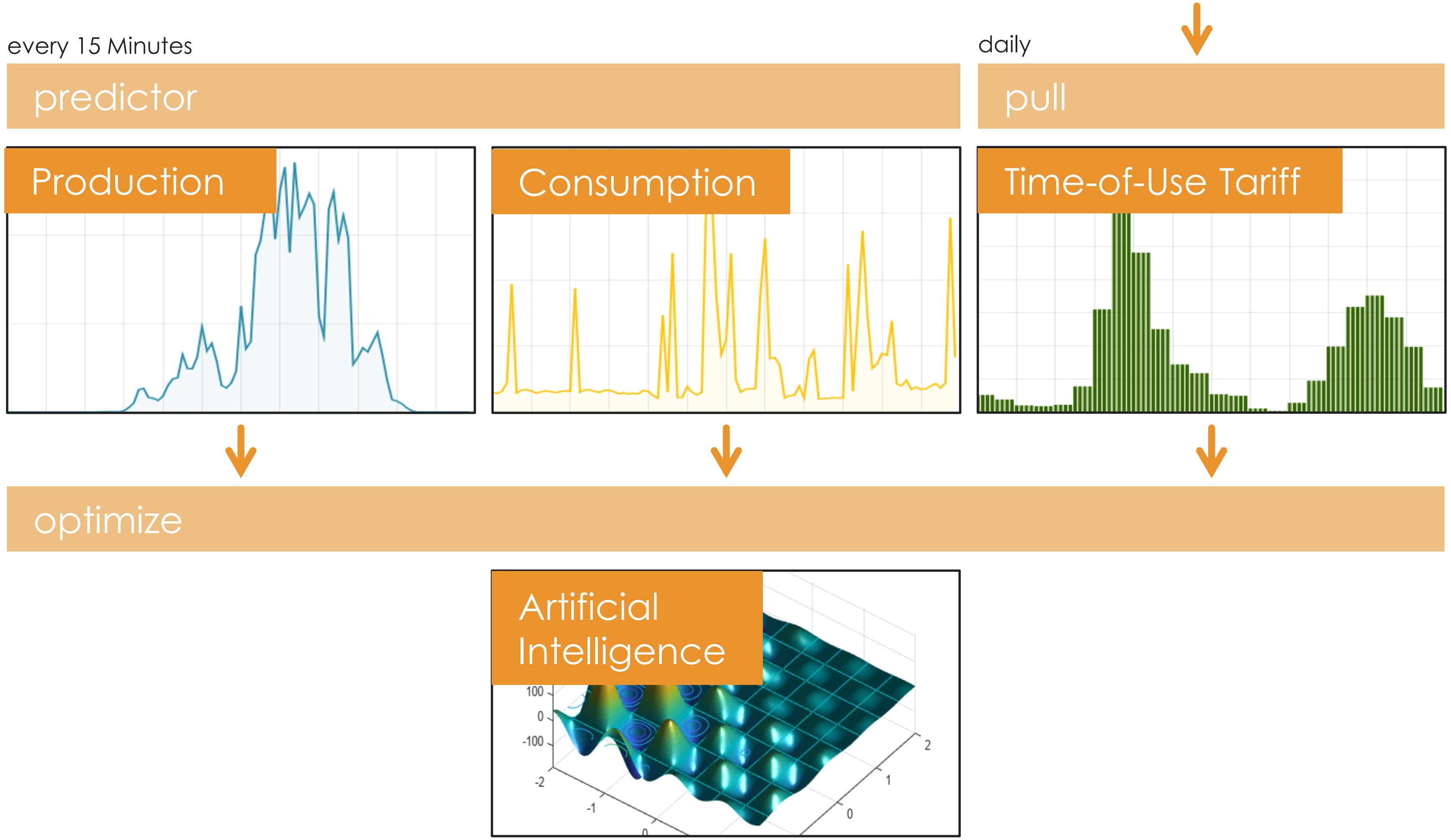
Production

Consumption

daily

pull

Time-of-Use Tariff



every 15 Minutes

predictor

Production

Consumption

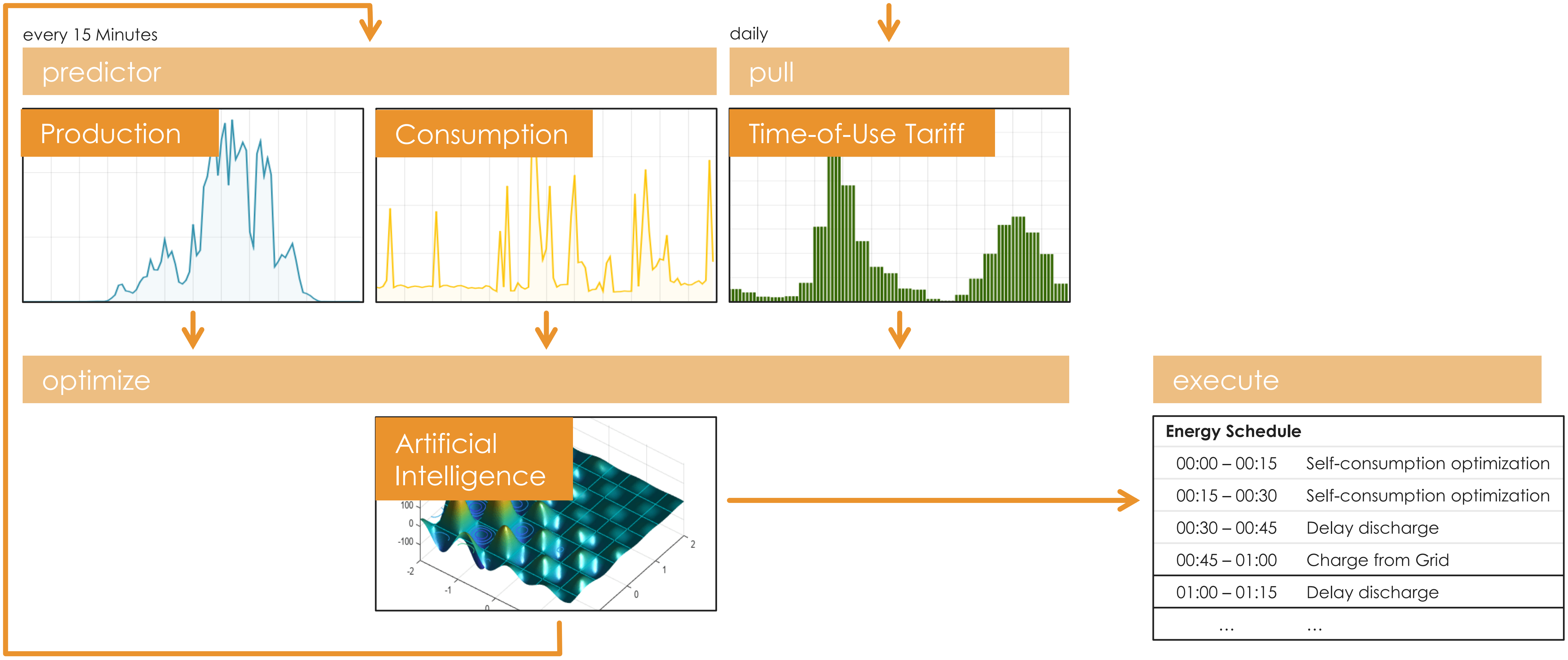
daily

pull

Time-of-Use Tariff

optimize

Artificial Intelligence



every 15 Minutes

predictor

daily

pull

Production

Consumption

Time-of-Use Tariff

optimize

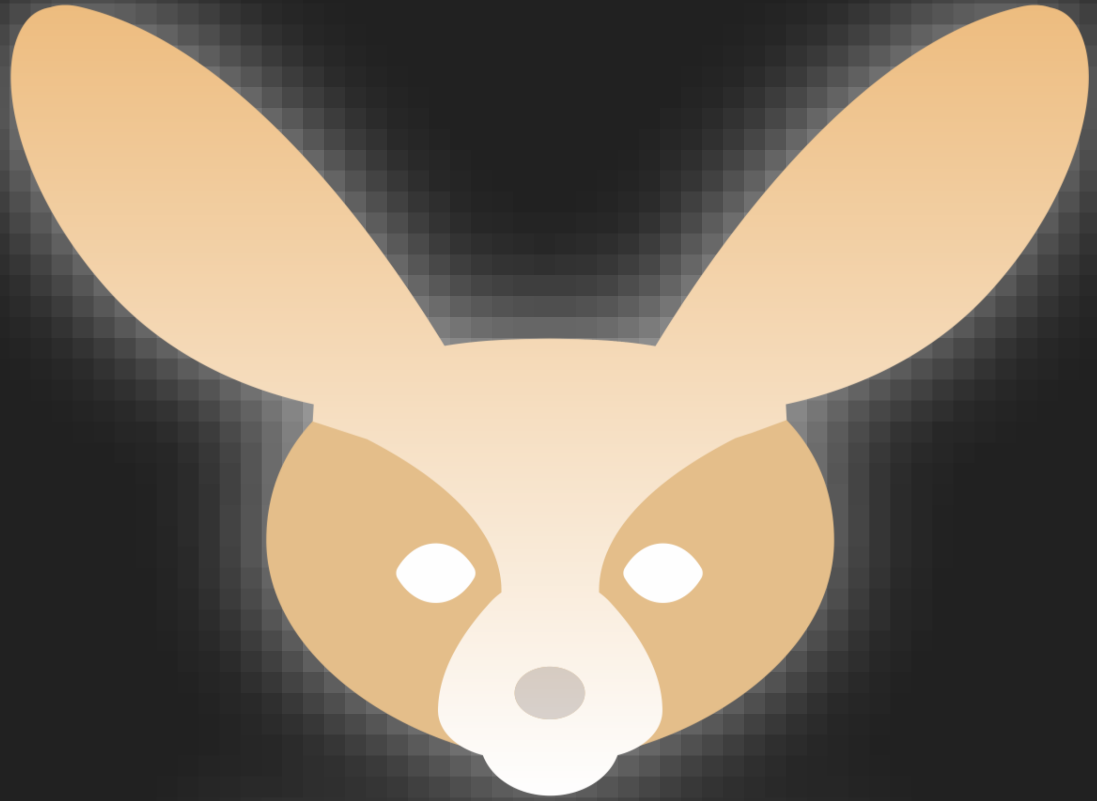
execute

Artificial Intelligence

Energy Schedule	
00:00 – 00:15	Self-consumption optimization
00:15 – 00:30	Self-consumption optimization
00:30 – 00:45	Delay discharge
00:45 – 01:00	Charge from Grid
01:00 – 01:15	Delay discharge
…	…

Code

- EnergyScheduleHandler: https://github.com/OpenEMS/openems/blob/develop/io.openems.edge.controller.ess.timeofusetariff/src/io/openems/edge/controller/ess/timeofusetariff/TimeOfUseTariffControllerImpl.java#L242-L279
- Energy API: https://github.com/OpenEMS/openems/tree/develop/io.openems.edge.energy.api/src/io/openems/edge/energy/api
- EnergyScheduler: https://github.com/OpenEMS/openems/blob/develop/io.openems.edge.energy/src/io/openems/edge/energy/EnergySchedulerImpl.java



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