Design of an Intelligent Energy Management System for a Hybrid Microgrid with Renewables and Battery Storage

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Content

Initial situation:

Situation

Context

- Global energy shift is creating a rising demand for sustainable, decentralized power systems.
- Hybrid microgrids are a solution to this demand, combining renewable energy sources and traditional energy sources, able to operate both grid-connected and standalone.
- Intermittency of renewable generators (solar PV) create supply-demand imbalances
- Need for intelligent energy management systems to ensure stability and cost efficiency arises

Design requirements

- Minimize cost of energy draw from the utility grid during grid-connected
- Optimum use of solar PV and BESS as renewable energy sources
- Ensure energy security during standalone mode
- Ensure power quality at the load terminals in both operating modes

Literature Review

Algorithms reviewed

Algorithms used in the models studied:

- Classical algorithms
- Metaheuristic algorithms
- Intelligent algorithms
  - ❑ Fuzzy logic
  - ❑ Artificial Neural Network
  - ❑ Deep Learning

Algorithms and their functions

Roles and priorities of the algorithms were:

- Prioritize price
- Prioritize sizing of microgrid
- Ensure voltage control
- Perform
  - ❑ Peak shaving
  - ❑ Curtailment

Load Data:

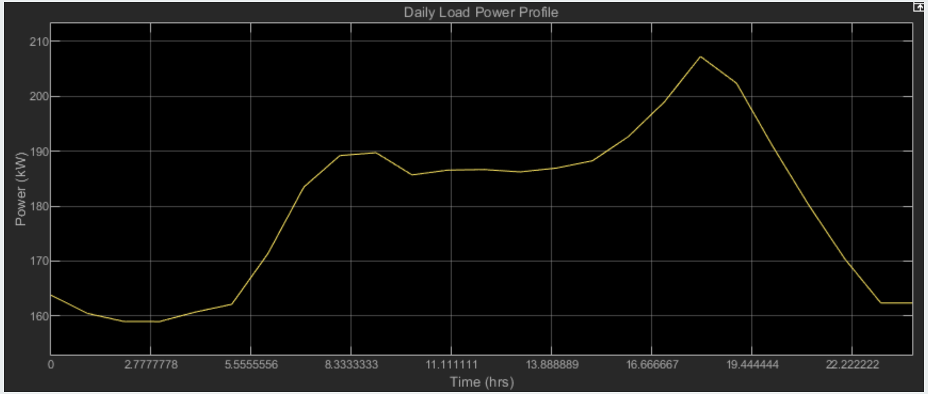
Data

Load Characteristics:

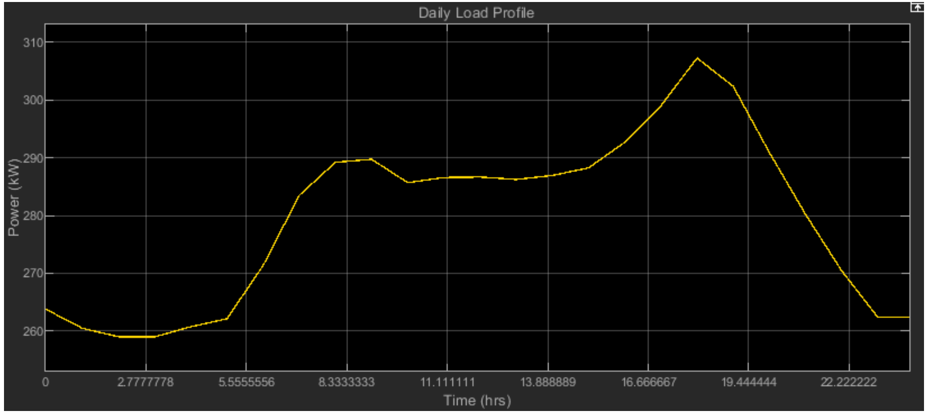
Load Characteristic	Energy (KWh)
Total	4326
Average	180
Maximum	206.4
Minimum	153

Load Profiles

Original sized load

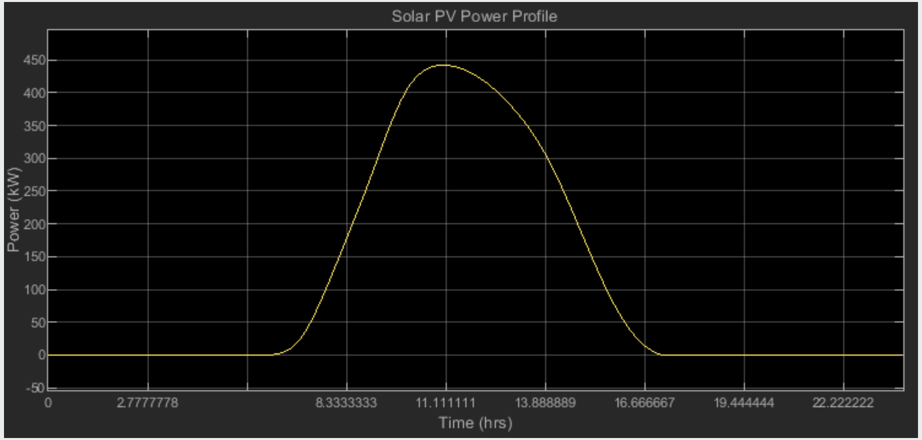


Increased load (additional constant load)



System components:

Solar Photovoltaic Panels (PV)

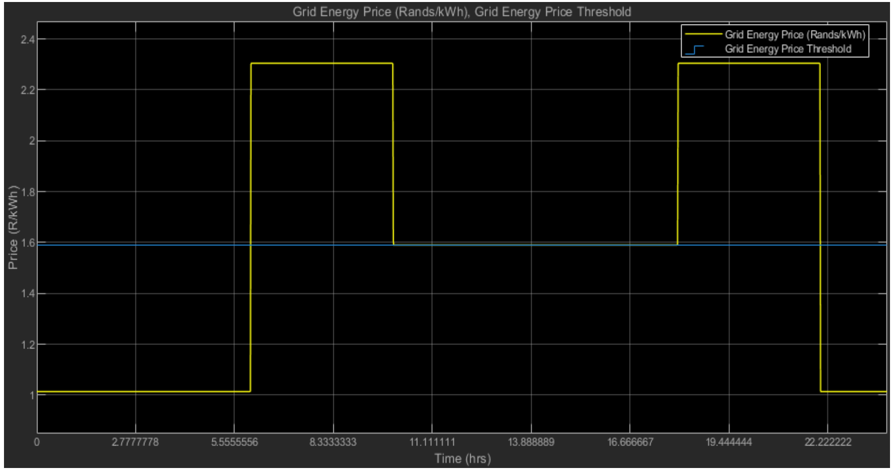


Key considerations

- Use of NASA Power Data to obtain weather data
- Radiance data and temperature data to calculate power losses (STC concept)
- Area is 2000m^2, efficiency of panels is 18%
- IEC 62548
- Total size is 472.43 kW

$$P_{pv}\ [\mathrm{W}] = N_{pv} \times G \times A \times \eta \times [1 + \alpha(T_c - T_r)]$$

Utility grid



Key considerations

- Use of utility grid based on low TOU tariff periods.
- Sized to export maximum of 500 MW, with voltage of integration of 400 V.
- IEEE1547

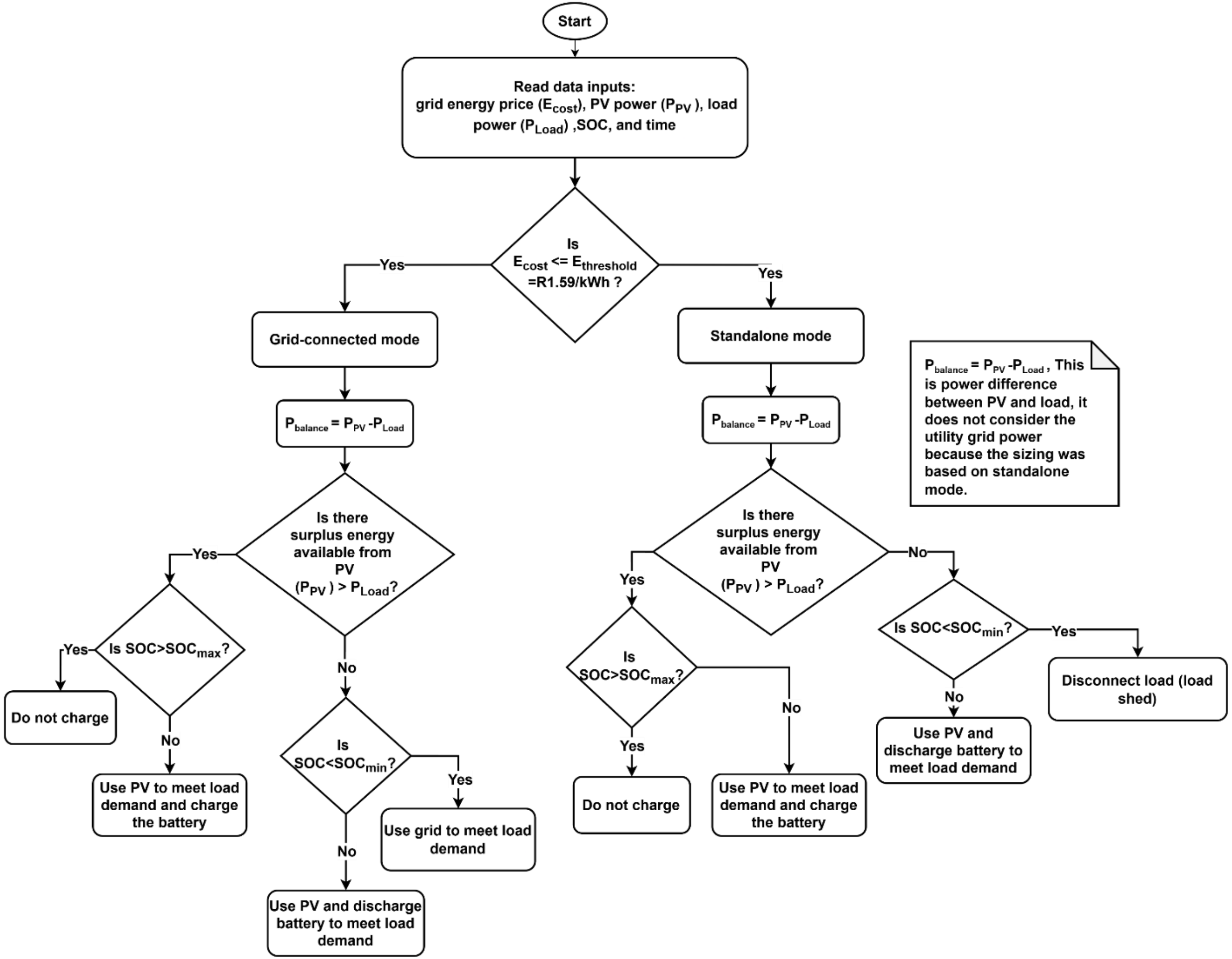
Battery Energy Storage System

Minimum dis/charge time	10 hours
Maximum power	300 kW
Maximum SOC	90%
Minimum SOC	30%
Dis/charging efficiency	95%
Battery inverter efficiency	96%

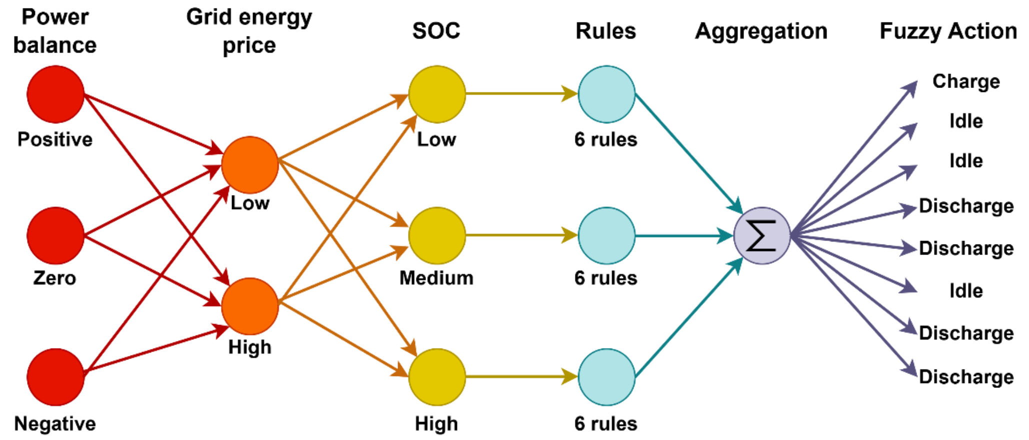
+ Storage capacity is 3000kWh, terminal voltage 400V.
+ Min and Max SOC of 30% to 90% extend battery life
+ FLC IEMS integrated with the BESS to schedule charging and discharging commands.
+ Sized to be able to absorb all PV surplus power.

The Algorithm:

High level Flow Diagram



Fuzzy Logic

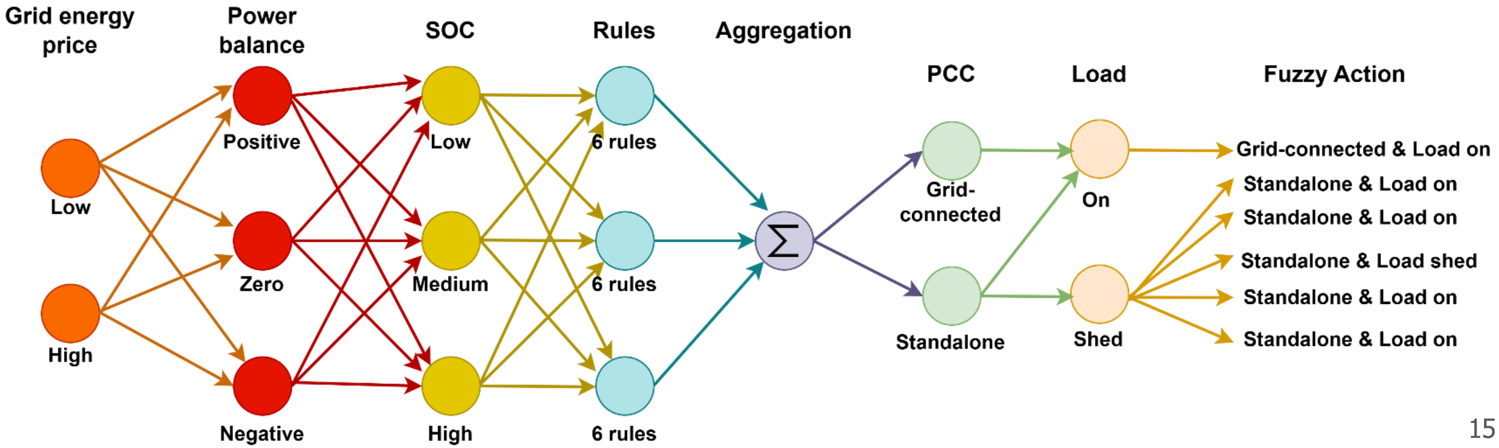


Mamdani FLC for BESS control

- Controls the charging and discharging pattern

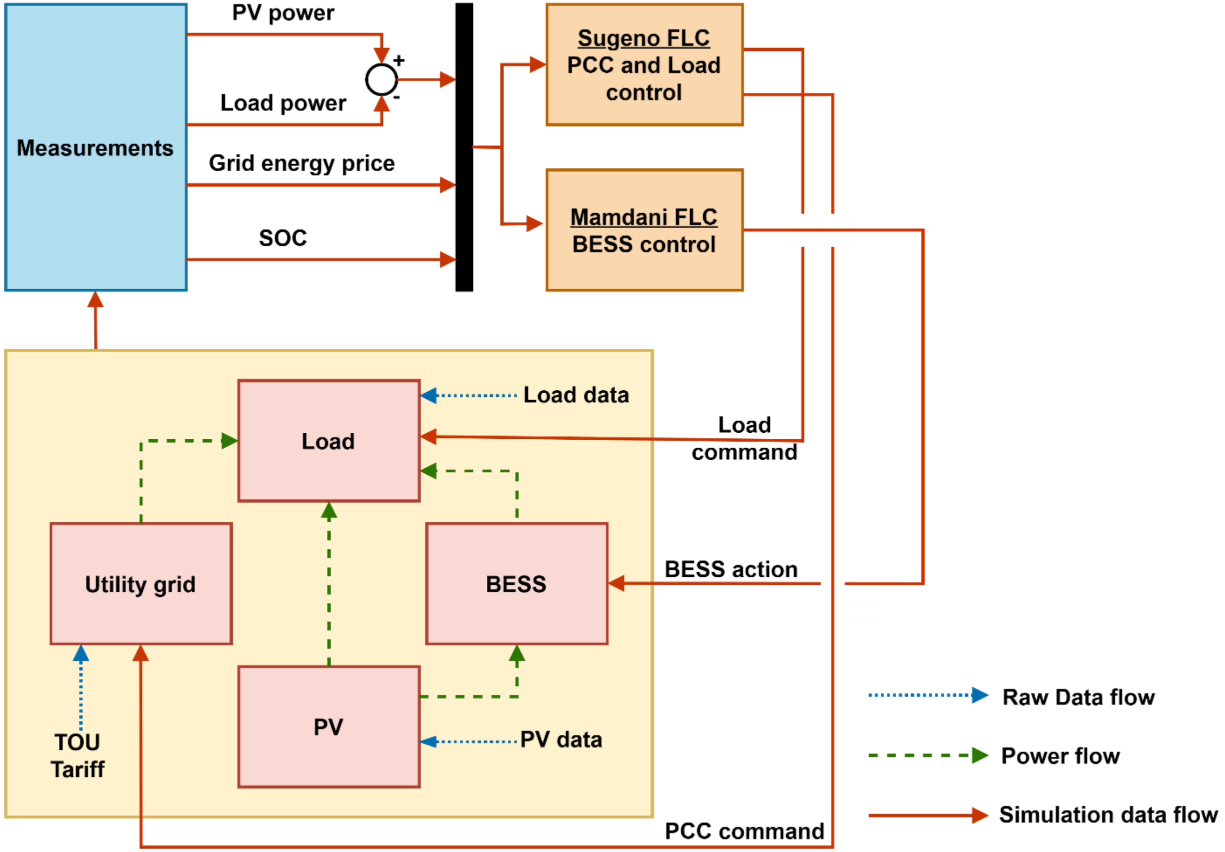
Sugeno FLC for mode and load control

- Controls mode of operation and load connection



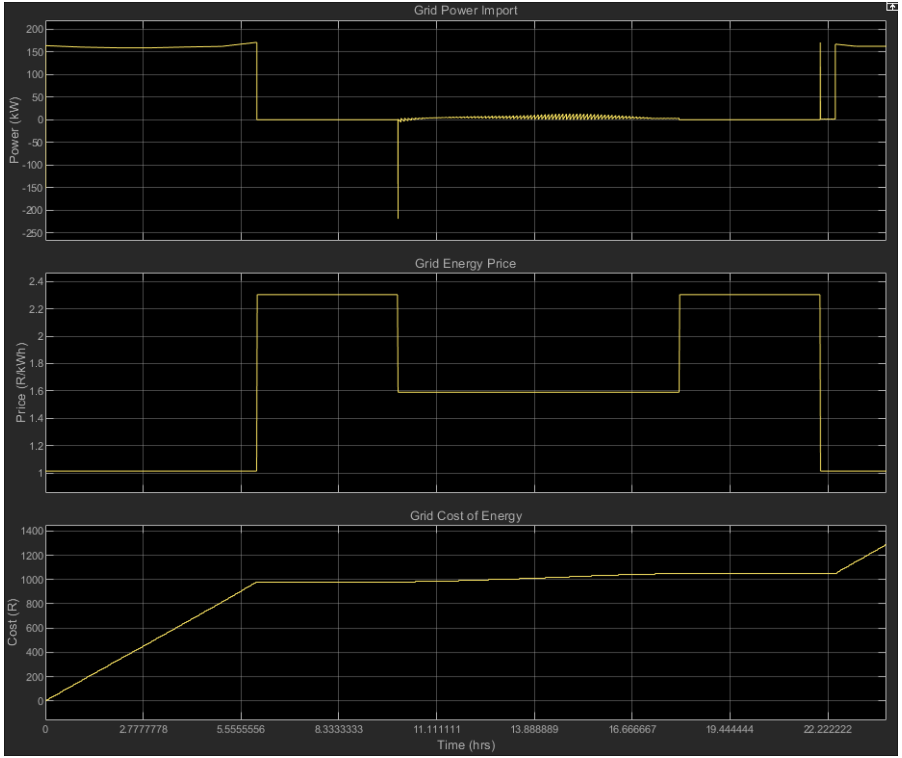
Integration:

Microgrid with FLC IEMS

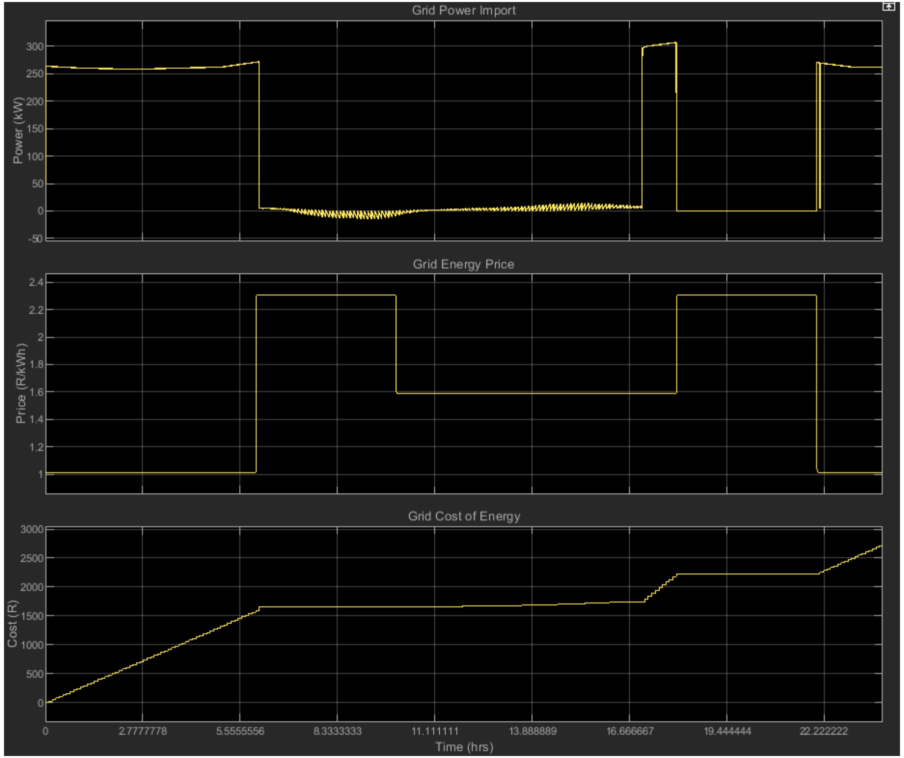


Results:

Simulation - Observations

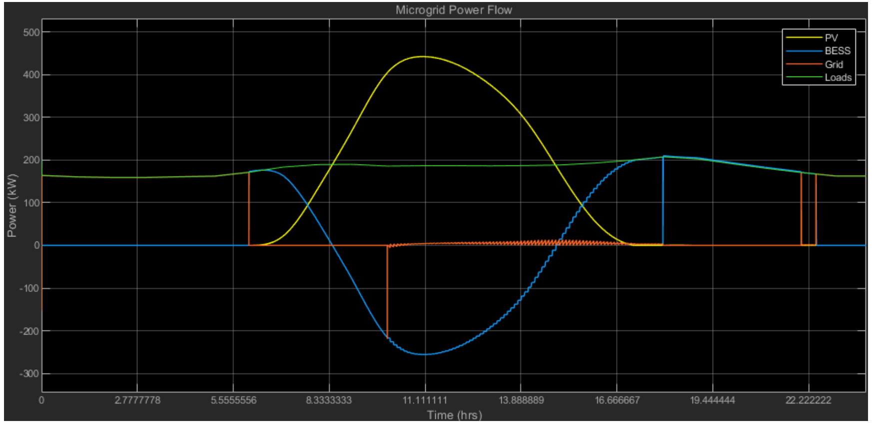


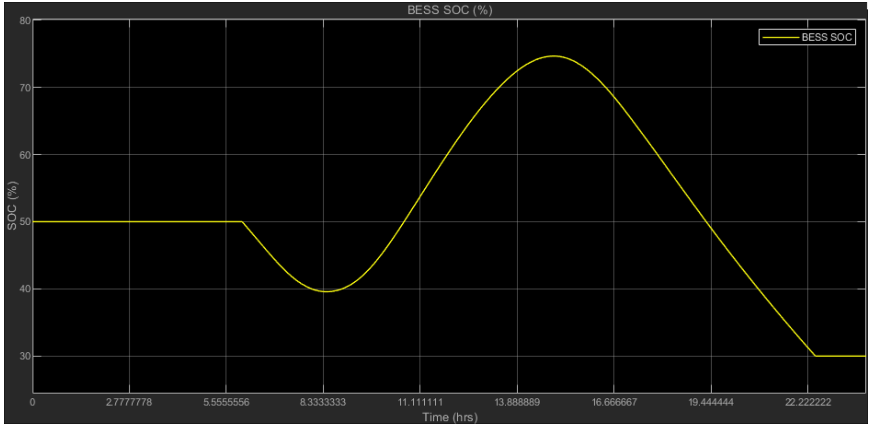
Case 3 grid power, TOU tariff and grid cost of energy

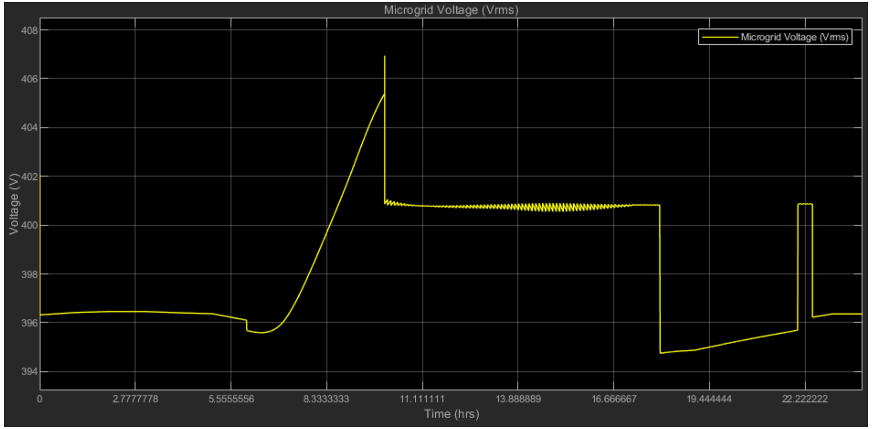


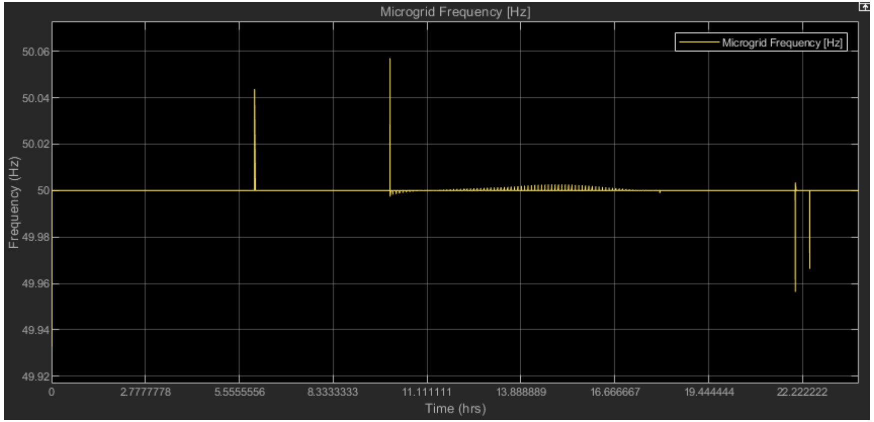
Case 4 grid power, TOU tariff and grid cost of energy

Simulation - Standard sized conditions

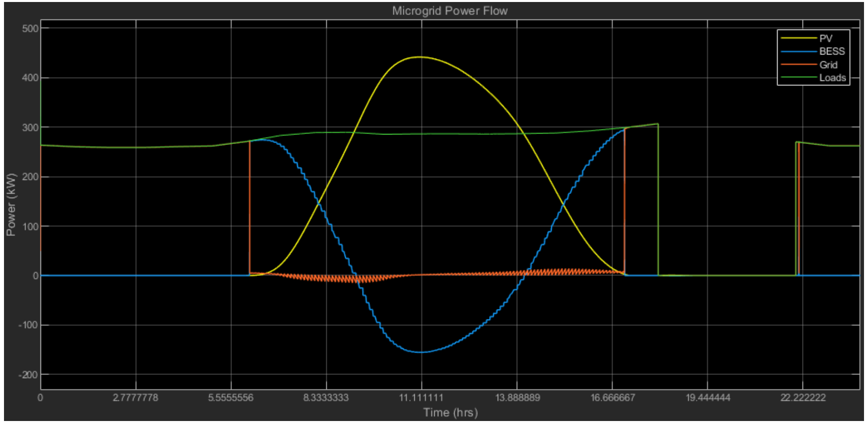


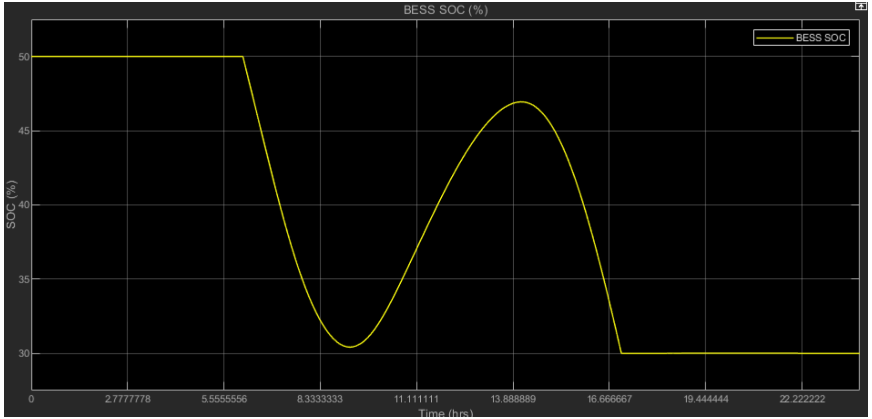


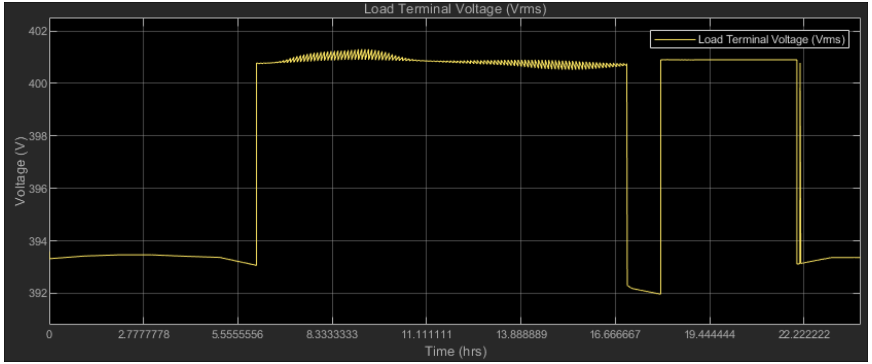


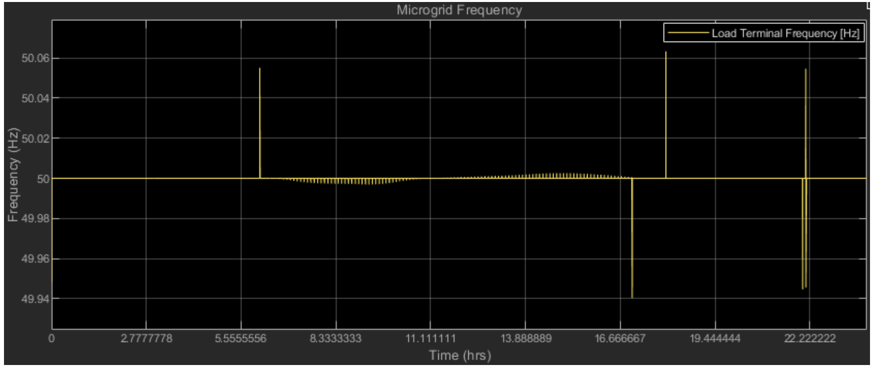


Simulation - Increased load

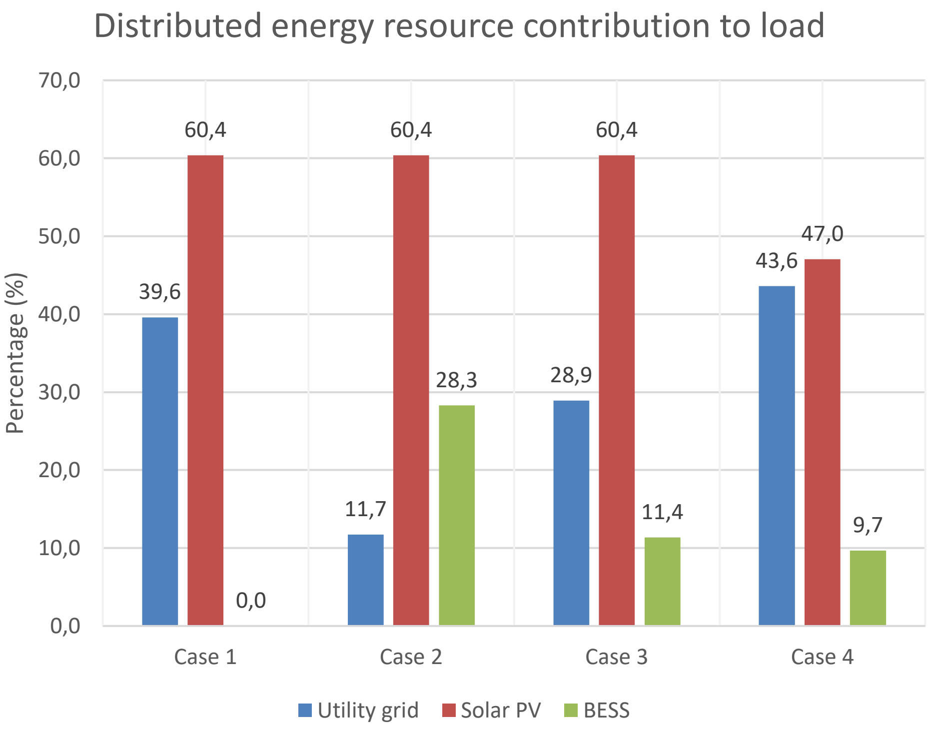


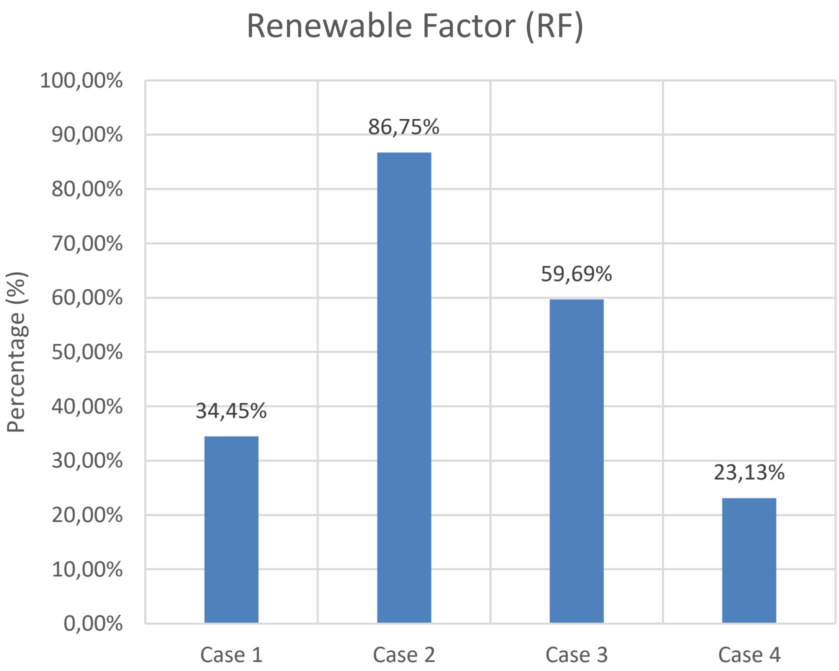




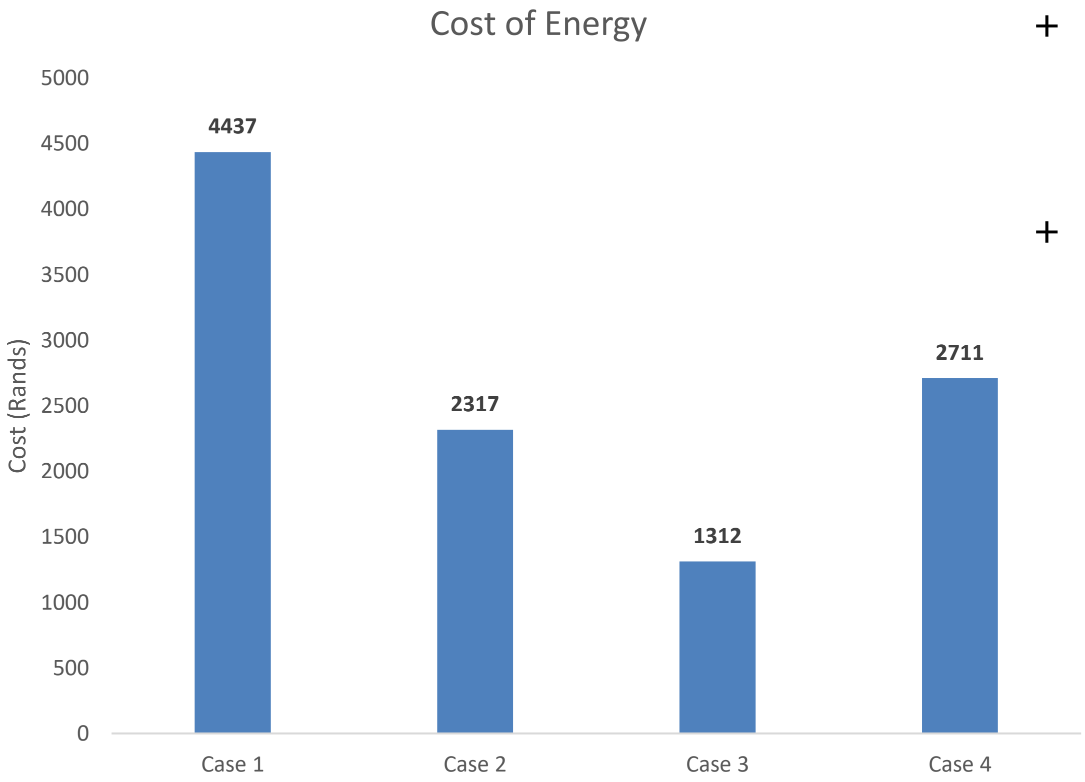


Results - Total Load Demand





Results - Total Cost of Energy



- Highest cost of energy from the utility grid was **R4437.00**, due to no FLC IEMS and BESS integration.
- Best case of **R1312.00** was achieved for the CoE due to implemented FLC IEMS with BESS.

Conclusion:

Key takeaways, the FLC IEMS was...

- Relevant since the power systems had more than 1 resource
- Necessary with hybrid renewable energy systems
- Used for cost reduction and satisfying demand by ensuring optimum use of DERs
- Different strategies for controls functions
- Ensure the power quality at the load terminals by ensuring minimal frequency fluctuations and voltage fluctuations doing DER power flow

THANK YOU!