FOSS Nanogrid Pilot

Pegasus Microgrid Summer School

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Outline

• Introduction
• Pilot site
• Demo Site Approach
• Results
• Conclusions
Introduction

• PEGASUS:
  ➢ Interreg-MED Project that aims to contribute to an increased, efficient and effective use of renewable energy sources (RES) using microgrid technologies
  ➢ Field Test in Cyprus: FOSS Lab area nanogrid
• The scope of the FOSS pilot is the implementation of a nanogrid that has the ability to operate in grid-connected and islanded modes
• Nanogrid: small microgrid topology where local small-scale generators and loads are connected
University of Cyprus

- Established in 1989
- New Campus located in eastern part of Nicosia
- 7,000 enrolled students

Vision: to create an energy optimal microgrid improving the energy efficiency of the campus and its zero energy green objectives
University of Cyprus – FOSS nanogrid

FOSS nanogrid location
FOSS Nanogrid Schematic

1.2.3: Office buildings
4: PV installations
5: Future Battery Energy Storage System
6: 10 kWh Battery Energy Storage System+3kWp PV installation
7: Controllable Electrical Load
8: EV charging/discharging station
FOSS Nanogrid Single Line Diagram + Components
FOSS Nanogrid Single Line Diagram + Components

Real Systems
- PV installations (34.9 kWp)
- 10 kWh Battery Energy Storage System (BESS)
- Smart Meters
- EV station
FOSS Nanogrid Single Line Diagram + Components

Real Systems
- PV installations (34.9 kWp)
- 10 kWh Battery Energy Storage System (BESS)
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Simulated Systems
- Battery Energy Storage System (200 kWh)
- V2G Operation of EV Station
FOSS Nanogrid Consumption Profile

- Consumption profile for a typical day
FOSS Nanogrid Generation Profile

- Generation profile of a day
FOSS Nanogrid Load Profile

• Generation, consumption, battery and net load profile of a typical day
FOSS Nanogrid consumption patterns

- Average hourly consumption: 5.04 kWh
- Average daily consumption: 121 kWh
- Minimum consumption observed: 1.61 kW
- Maximum consumption observed: 44 kW
FOSS Nanogrid Tested Use Cases

- Powersim model developed to test various use cases:
  - Grid-connected operation: Balancing the flow at Point of Common Coupling (PCC)
  - Islanded operation: Stabilizing nanogrid under different dynamic load conditions
  - Transition from Grid-Connected to Islanded Mode and vive-versa
Simulations - Transition from grid-connected to islanded mode

- $t=0.4$ s: main grid collapses -> nanogrid goes into islanded mode
- BESS switches to grid-forming operation mode
- PV and BESS cover total load demand
Simulations - Transition from islanded to grid-connected mode

- Synchronization process to implement smooth transition
- BESS adjusts voltage and frequency of nanogrid
- Voltage synchronization process forces nanogrid PCC voltage towards main grid PCC voltage
- Phase synchronization process forces nanogrid phase angle towards main grid phase angle
Financial Assessment of FOSS Nanogrid. Use Case

- Installation of PV systems and Battery Storage
- Pricing scheme: Net – billing Scheme with ToU tariffs
- 20 years planning period
- Target: maximization of self-consumption and electricity bill cost minimization utilizing the provided tariff
## Financial assessment of FOSS nanogrid. Use Case

- Remuneration of energy fed back to the grid: 10.2 cents/kWh,
- ToU tariff for electricity consumption

<table>
<thead>
<tr>
<th>Months</th>
<th>Days</th>
<th>Hours</th>
<th>Price Periods</th>
<th>Energy Price (€ kWh(^{-1}))</th>
<th>Fixed Fee (€)</th>
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<tbody>
<tr>
<td>October to May</td>
<td>Monday to Friday</td>
<td>16:00 – 23:00</td>
<td>P1</td>
<td>0.1783</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>23:00 – 16:00</td>
<td>P2</td>
<td>0.1644</td>
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<td>Weekends</td>
<td>16:00 – 23:00</td>
<td>P3</td>
<td>0.1738</td>
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<tr>
<td></td>
<td></td>
<td>23:00 – 16:00</td>
<td>P4</td>
<td>0.1605</td>
<td>0.086 per day</td>
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<tr>
<td>June to September</td>
<td>Monday to Friday</td>
<td>09:00 – 23:00</td>
<td>P5</td>
<td>0.2229</td>
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<td></td>
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<td>23:00 – 09:00</td>
<td>P6</td>
<td>0.1745</td>
<td></td>
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<tr>
<td></td>
<td>Weekends</td>
<td>09:00 – 23:00</td>
<td>P7</td>
<td>0.1771</td>
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<td>23:00 – 09:00</td>
<td>P8</td>
<td>0.1719</td>
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Preliminary economic assessment of the FOSS nanogrid

• Cost-Benefit Analysis for Nanogrid

<table>
<thead>
<tr>
<th>Benefits</th>
<th>Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>▪ Increase of self-consumption and reduction of electricity bill</td>
<td>▪ Capital investments: initial capital investment for purchasing and installing the equipment</td>
</tr>
<tr>
<td>▪ Sale of generated electricity</td>
<td>▪ Construction and operational costs: costs for the EMS, installed capacity of energy storage systems and PV, control devices, monitoring systems</td>
</tr>
<tr>
<td>▪ Energy savings and emission reduction: serve the EU’s long-term goal of power sector decarbonisation and help to reduce CO₂ and SO₂ emissions</td>
<td>▪ Maintenance costs: Costs for the maintenance of the equipment</td>
</tr>
<tr>
<td>▪ Improvement of electricity reliability and power quality: prevent sustained outages, provide ancillary services (e.g. frequency support, black-start capability, peak load saving, etc.)</td>
<td></td>
</tr>
</tbody>
</table>
Conclusions

• FOSS nanogrid capable of operating in grid-connected and islanded modes
• Financially beneficial and viable solution
• Approach of the pilot study could be broadly applicable to large-scale microgrids
• Future work:
  ➢ Further integration of data measurements to optimize nanogrid model
  ➢ Simulations in DIgSILENT environment
  ➢ Finalization of Cost Benefit Analysis
Thank you for your attention!

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www.foss.ucy.ac.cy