Virtual Power Plants (VPP)

Alexis Kwasinski, Ph.D.

R. K. Mellon Faculty Fellow in Energy

University of Pittsburgh, Swanson School of Engineering

Overview

- What is a virtual power plant?
- Potential benefits and issues
- Example / Application
- Conclusions

What is a VPP?

- **High-level view**
  It is an aggregation of loads and distributed resources (customer side power generation and energy storage) that can be commonly controlled by the same entity under a demand-side management agreement.

- **A closer look at what are VPPs**
  Why it is virtual? Because for the grid operator, VPPs may behave like a negative load.

- Without coordinated control may affect matching supply with demand.

Potential benefits and issues

Benefits and Issues is a matter of perspectives

- Who pays for the VPP assets?
- Who benefits from the VPP assets?
  - Operation of VPP is as much as a regulatory and economic issue as a technical issue
- Perspective change depending the application scope (e.g., microgrids, power grids, etc.).

- **Benefits**
  Better resource utilization (e.g. for enhanced efficiency or availability).
- **Issues**
  Stability, coordinated control, planning.

Application Example

Goal

- Increase the use of renewable energy sources for wireless communication networks

Issues when trying to achieve this goal through conventional means:

- Issues with PV systems:
  - Large footprints (PV: 250 W/m2 vs. base station: 1.5 kW/m2)
  - Variable output (part stochastic, part deterministic)
- Issues with wind generators in cities:
  - Wind profiles and aesthetics

Past proposed solutions:

- Use of energy storage (batteries)
- Diversify power sources

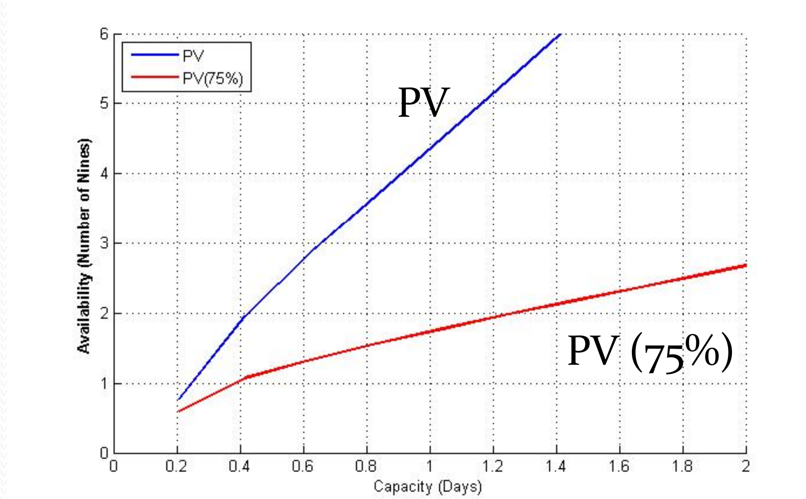
Application Example

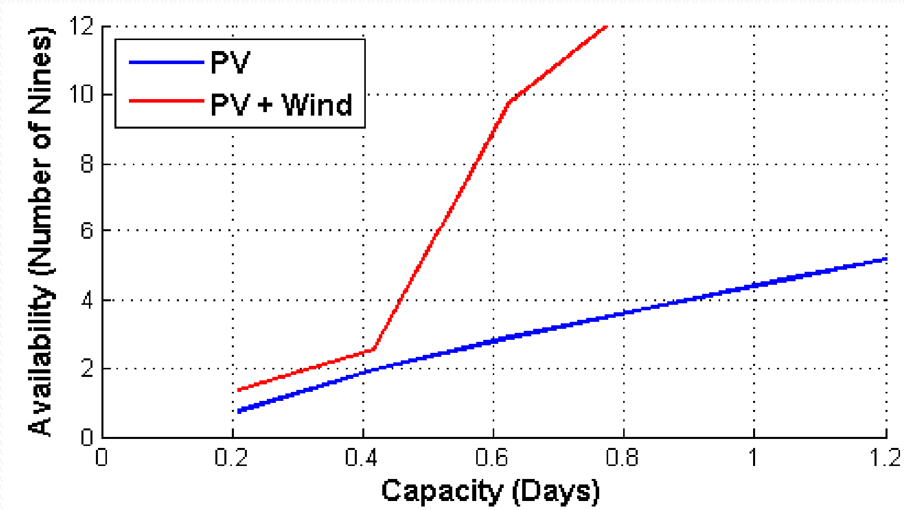
Goal

- Increase the use of renewable energy sources for wireless communication networks

Issues with proposed past solutions

- **Significant energy storage capacity is needed**





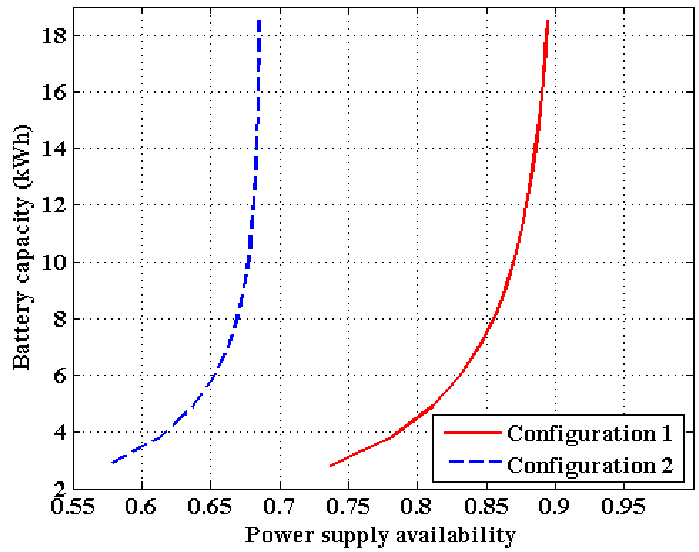
Application Example

Goal

- Increase the use of renewable energy sources for wireless communication networks

Issues with proposed past solutions

- **There is a limit to the effectiveness of added energy storage**



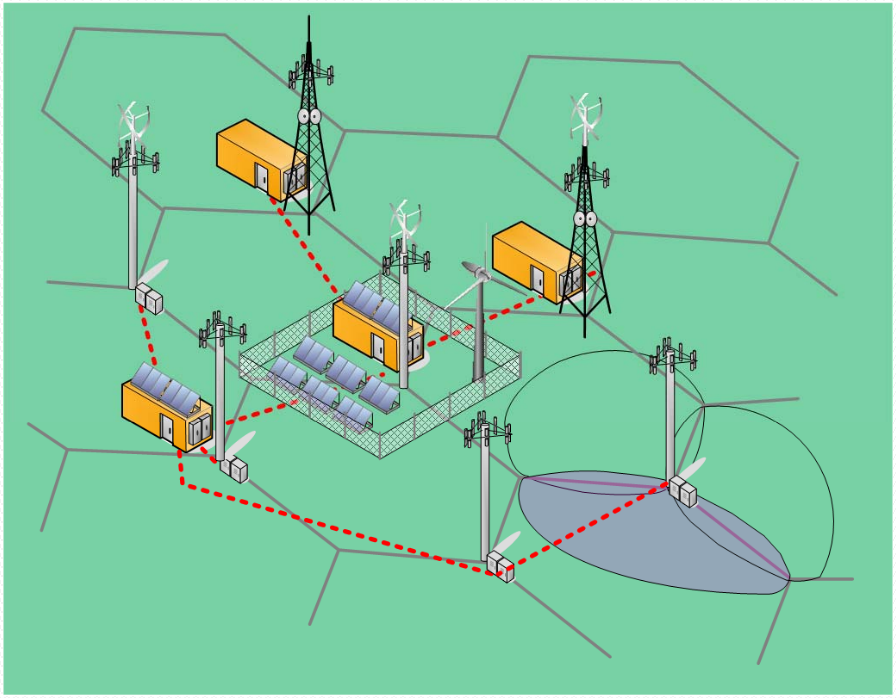
- Configuration 1: 6 x MX60-240 PV modules + 1 x Excel 10 kW wind turbine,
- Configuration #2 : 20 x MX60-240 PV modules

Application Example

Goal

- Increase the use of renewable energy sources for wireless communication networks

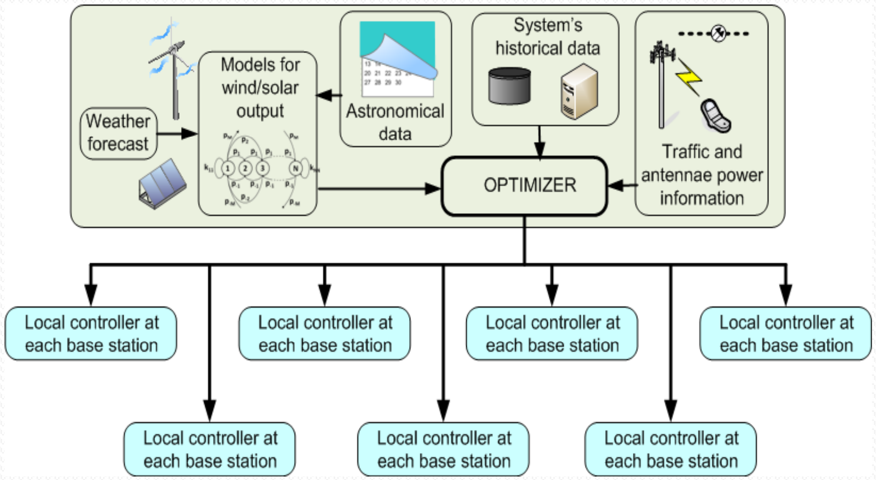
- **Approach:**
  Integrated management of power generation, energy storage and load within acceptable users quality of experience levels.
- **Type of system:**
  DC microgrid with power electronic circuits controlling power flows.



Application Example

Operation and control

- Hierarchical structure
- **Top level:**
  Demand side management (traffic control) coordinated with power generation and energy storage management
- **Lower level:**
  Local droop regulators.



Application Example

Load control

- Base station power consumption:

$$P = P_B + \sigma \upsilon P_T$$

- **Traffic shaping approach:**

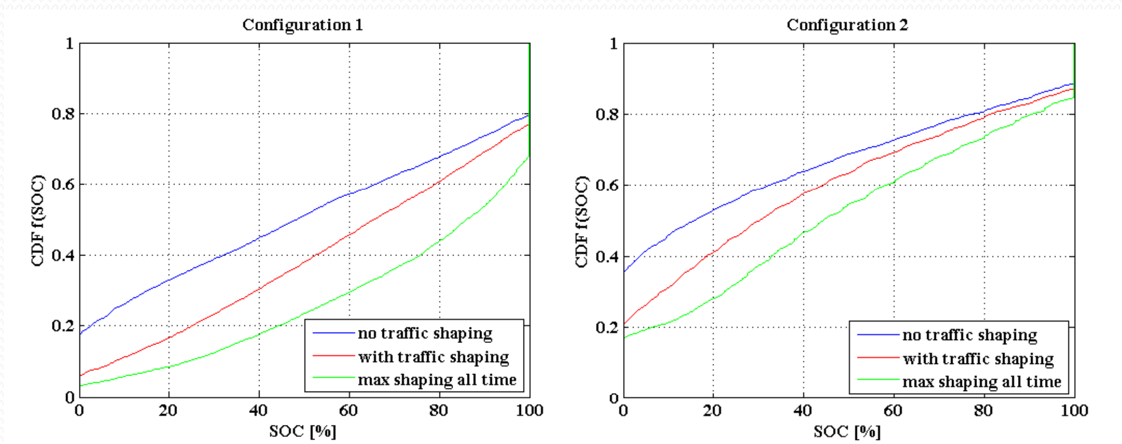
σ is modified as needed in order to limit the traffic and, thus, reduce the power consumption of the base station while still providing acceptable quality of user experience levels.

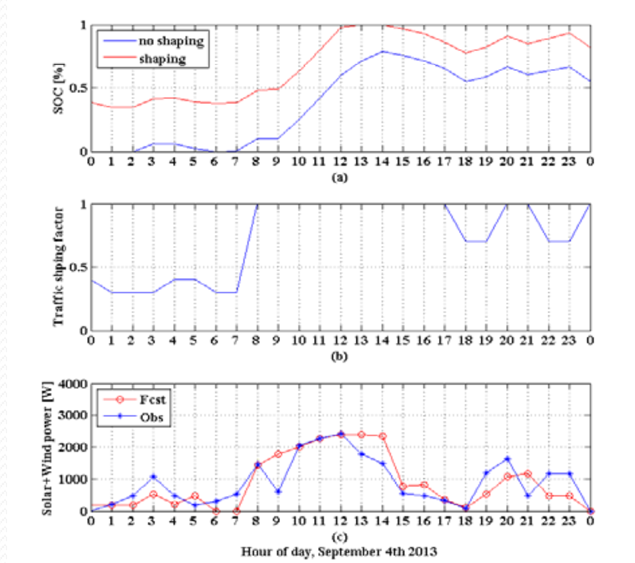
Algorithms used to modify σ are out of the scope of this presentation. Weather forecast is used to optimize operation.

Application Example

Results

- VPP-based control allows for better resource utilization yielding:
  - 25 % improvement in availability.
  - 10 % improvement in battery life
  - 25 % reduction in battery bank capacity for a same availability
  - 40 % reduction in PV array size for same performance.





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Conclusions

- With proper control VPP can be a suitable approach for improved performance both in conventional power grids and in microgrids.
- Potential issues for the implementation of VPP are stability concerns and regulatory limitations.
- In many applications who invests in the VPP may not necessarily be the party who benefits the most from it.
- A practical case of VPPs used to expand the use of renewable energy sources in wireless communication networks is provided in order to exemplify some of the potential advantages of their use.