Challenges in Enabling Resilience with Microgrids

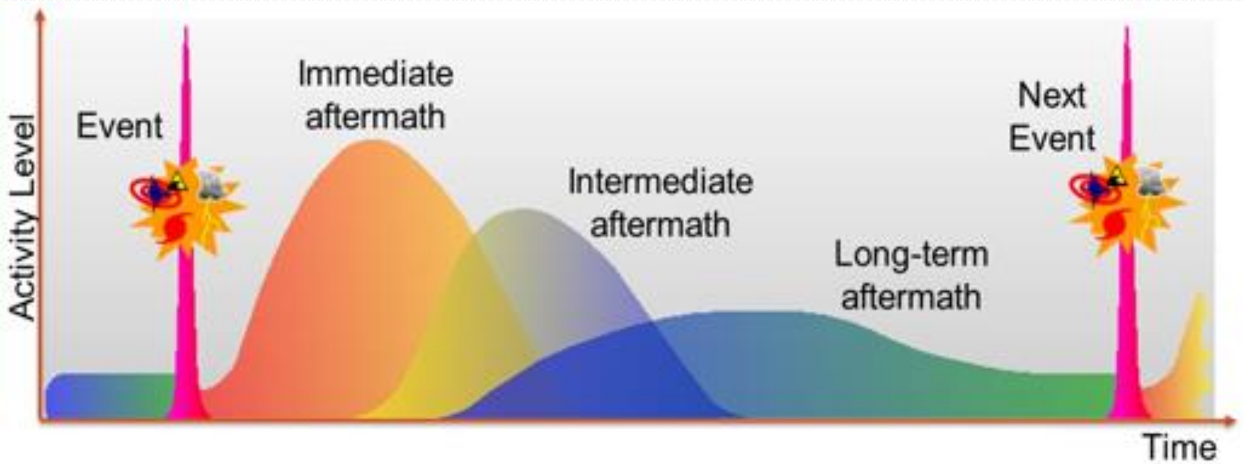
Alexis Kwasinski, Ph.D.

University of Pittsburgh, Swanson School of Engineering

Resilience

Definition

- Based on U.S. Presidential Policy Directive (PPD) #21
- **PPD-21 defines resilience "as the ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions.**



Resilience

- Broader Resilience Definition from U.S. PPD-21
- **Four components of resilience:**
  - **Ability to prepare for changing conditions**
  - **Ability to adapt to changing conditions**
  - **Ability to withstand disruptions (depends mostly on hardware)**
  - **Ability to recover rapidly from disruptions. (depends on hardware and on human driven processes)**
- **Focus here is in the last two components**
- **Various temporal scales: short term, medium term, long term**
- Since one of the components of resilience is recovery speed, the notion of resilience accepts having service outages because high resilience can be achieved even when there is there is an outage if service is restored sufficiently fast.

eLEAdERS

Resiliency Metrics

Resiliency (from PPD21):

- The ability to **prepare** for and **adapt** to changing conditions and **withstand** and **recover rapidly** from disruptions.

- "Withstand" refers to an "up" time
- Rapid recovery refers to a "down" time

- Inclusion of an up and a down time points towards an analogy between the concept of base resiliency and that of availability.

- Preparation and adaptation relates to the influence of processes through the down time.

eLEAdERS

Resilience Metrics

- Local resilience including energy storage:

$$R_L = 1 - \left(1 - \frac{T_{U,G}}{T_{U,G} + T_{D,G}}\right) e^{-T_{S,B}/T_{D,G}}$$

where $T_{S,B}$ is the energy storage autonomy provided by batteries, $T_{U,G}$ is the expected time the system will remain powered from a grid during an extreme event, such as a natural disaster, and $T_{D,G}$ is the expected power grid tie down time during an extreme event.

- Challenges:
  - Down time is in particular heavily influenced by human driven process (e.g., logistics, spares and resources management).
  - Direct measurement of planning, preparedness and adaptation capabilities.

Microgrids Resilience

- Lifeline-dependent power sources:
- Approaches to mitigate lifeline dependencies:
  - Use of **diverse power source technologies** (e.g. combine natural gas and diesel, or natural gas and renewable energy sources)
  - **Local energy storage** (e.g. diesel tank) – local energy storage serves to:
    - Quantify degree of functional dependence
    - Reduce lifeline dependencies

LEAdERS

Microgrids Resilience

- Power sources converting renewable energy:
- Most renewable energy sources do not require lifelines, but…..
- Issues with PV systems:
  - Large footprints
  - Variable output (part stochastic, part deterministic)
- Issues with wind generators in cities
  - wind profiles and aesthetics

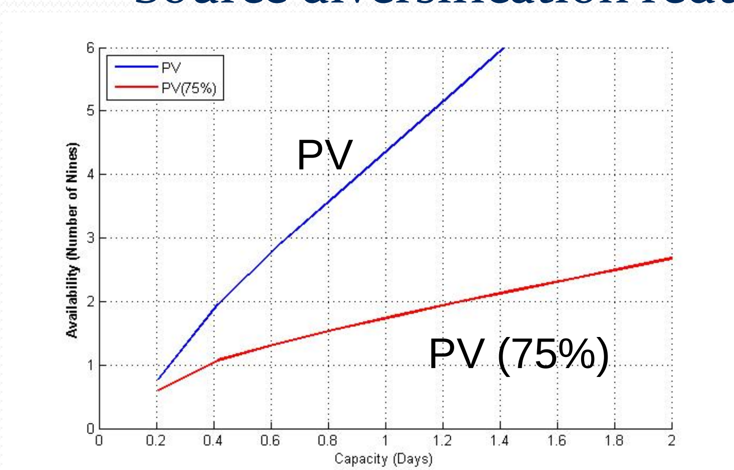
2x350 kW
natural gas
generators

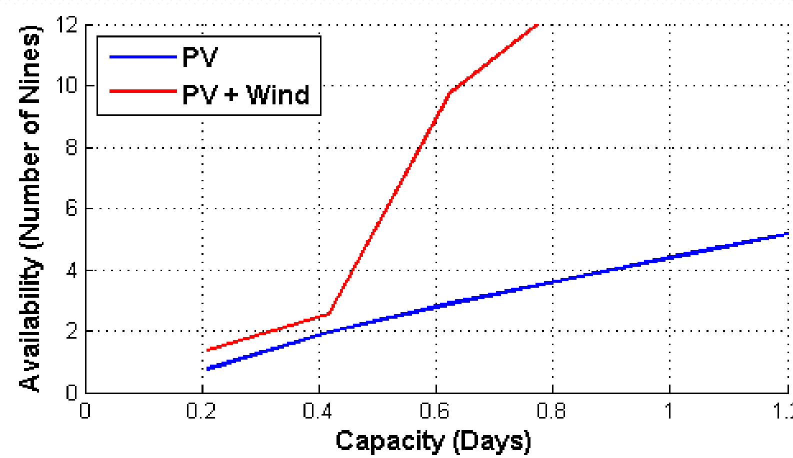
50 kW
PV array

Microgrid
in Sendai

Microgrids Resilience

- Solutions to issues with renewable energy sources:
    - Combine them with local energy storage (e.g. batteries)
        - Very high availability requires significant stored energy
    - Diversify power sources (e.g. combine wind and PV)
        - Source diversification reduces energy storage capacity needs





LEAdERS

Conclusions

- Challenges in measuring resilience:
  - Effects of human driven processes during restoration
  - Direct evaluation of planning, preparedness and adaptation.
- Key design aspects for enhanced microgrids resilience:
  - Integration of energy storage
  - Use of diversified power sources (preferably at least one of the types of sources should be from renewable energy).
- Costs of implementing resilience improvement measures are substantial… may require support in terms of subsidies.

LEAdERS

Thank you very much

Questions?

Alexis Kwasinski

(akwasins@pitt.edu)

University of Pittsburgh

PITT | SWANSON ENGINEERING
ELECTRICAL & COMPUTER

LEAdERS @PITT