Microgrids

Siddhartha Nigam, Avesta Hojjati
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University of Illinois at Urbana-Champaign

OUTLINE

- Definition of a microgrid – *μg*
- Motivation towards a *μg*
- *μg* concepts and salient features
- Examples of *μg* implementations
- *μg* benefits and roles
- Questions and conclusions

OBJECTIVES

- To understand the motivation behind μgs
- To get an overview of the concept of μg and highlight the salient features
- To view some working demonstrations of a μg and realize the broad ranges of μgs
- To understand the μg benefits and roles

MICROGRID - DEFINITION

A microgrid is a network of interconnected loads and distributed energy resources, within clearly defined geographic boundaries, with the properties that it is a single controllable entity with respect to the grid and that it operates either connected to or disconnected from the grid, *i.e.,* in either the *grid connected* or in the *islanded* mode.

MOTIVATION TOWARDS A *μg*

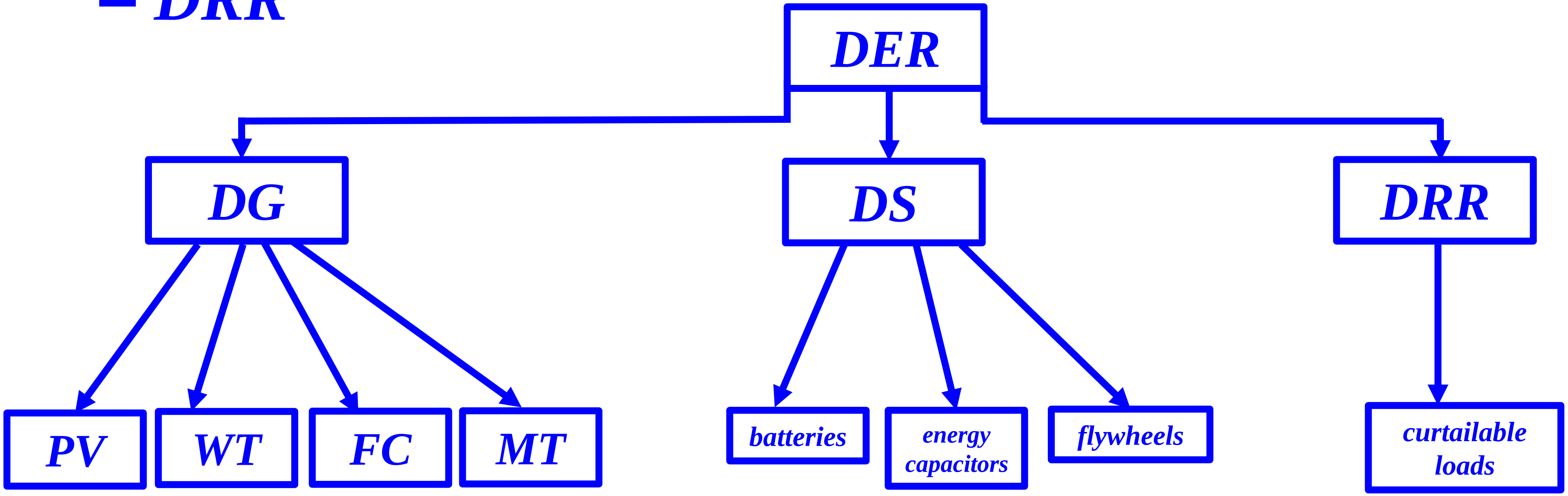
- As the economy expands, the need for additional electricity generation and transmission resources arises to meet the increased demand
- Today’s transmission system is heavily stressed during peak hours with extensive grid congestion
- The integration of the deeper penetration of renewable resources further increases the need for transmission expansion – a major challenge in terms of the environmental and cost barriers that must be overcome

MOTIVATION TOWARDS A *μg*

- **The antiquated *US* grid is increasingly subject to weather incidents, such as storm *Sandy* in 2012, and cyber attacks, which may result in major social and financial impacts**
- **Given the status of the grid and the difficulties in the implementation of grid expansion plans, there is a need to drive some resources further down into the distribution system to ensure reliable electricity supply**

MOTIVATION TOWARDS A *μg*

- **Over the years resources were connected at sub-transmission and distribution voltage levels, referred to as distributed energy resources – *DER* which may include distributed generation and storage – *DG, DS* and demand response resources – *DRR***



MOTIVATION TOWARDS A μg

- DER have provided relief to few of the problems stated before though it must be recognized that deeper penetration of DER will demand wider control and management
- With deeper penetration of DER and no control, they may have a significant impact on the power balance
- A possible solution to this problem is the deployment of the microgrid – μg

THE MICROGRID CONCEPT

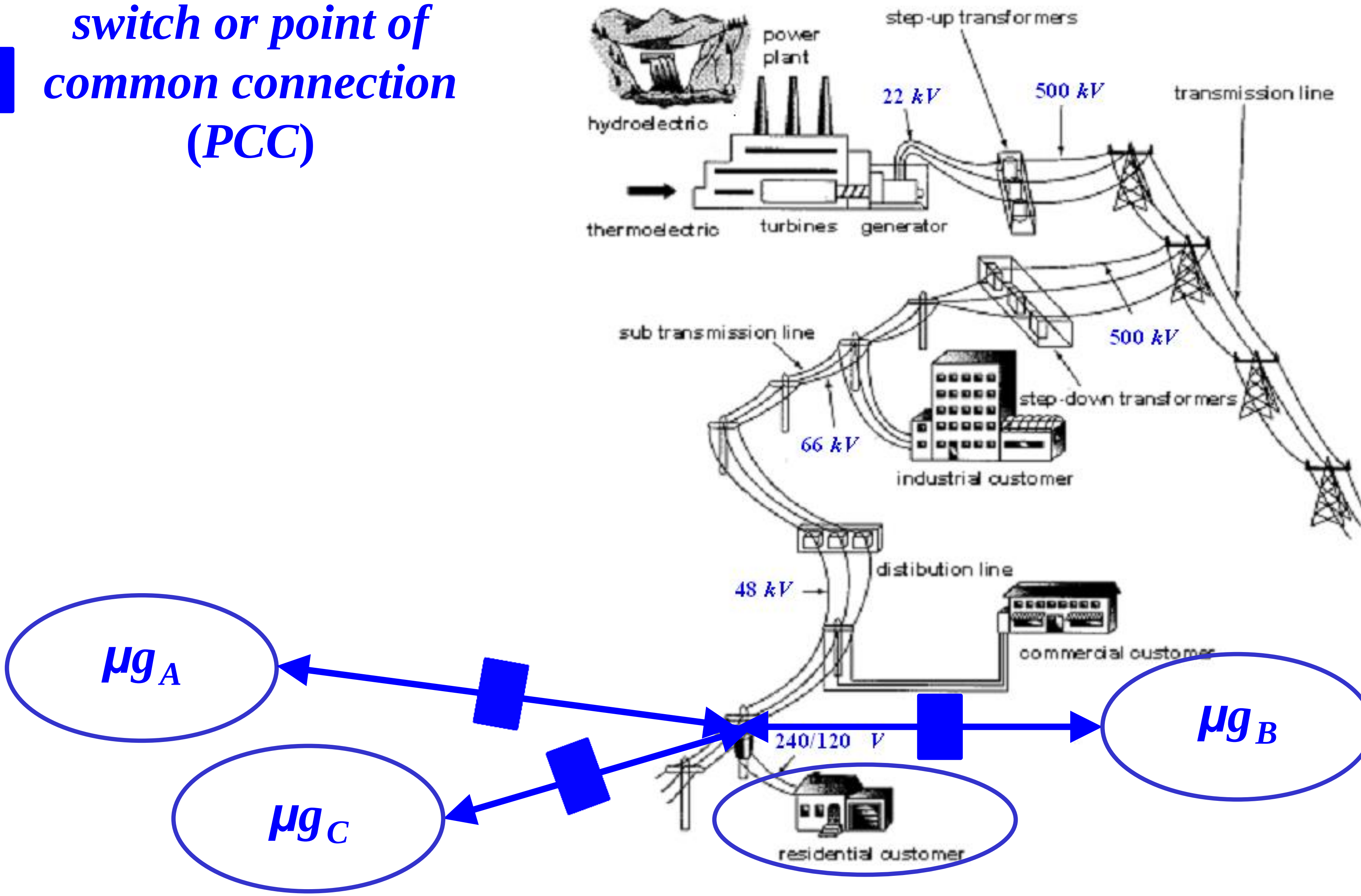
- μgs provide a systematic approach which interconnects the *DER* and loads and views it as a subsystem and hence provides a better control over the *DER*
- μgs generate and distribute electricity to loads but do so on a purely local scale
- μgs may be seen simply as an alternative reconfiguration of power systems than the transmission – level interconnections that are so widely used

THE MICROGRID CONCEPT

- The key difference between the *μg*s and the early 20th century isolated power system designs is the ability of *μg*s to operate in both a connected mode to, as well as an islanded mode from, the grid
- When connected to the grid, the *μg*s make full use of the advantages of an interconnected grid
- Under normal and contingency cases, the *μg* can disconnect to form an island and to make use of the local generation to maintain continuous supply to its loads

THE MICROGRID CONCEPT

switch or point of common connection (PCC)



SALIENT μg FEATURES

- μg implementation is generally carried out at the lower voltage levels of the distribution system with the integrated generation resources
- The rapid pace of μg implementation has resulted in a broad range of projects that vary from a few kW to several MW depending on the application
- The two μg operation modes are sometimes referred to as parallel or grid tied mode and islanded or isolated mode

SALIENT μg FEATURES

- The μg load comprises both commercial and residential consumers

- The μg supply resources are distributed generation units of renewable and non-renewable resources and include energy storage devices

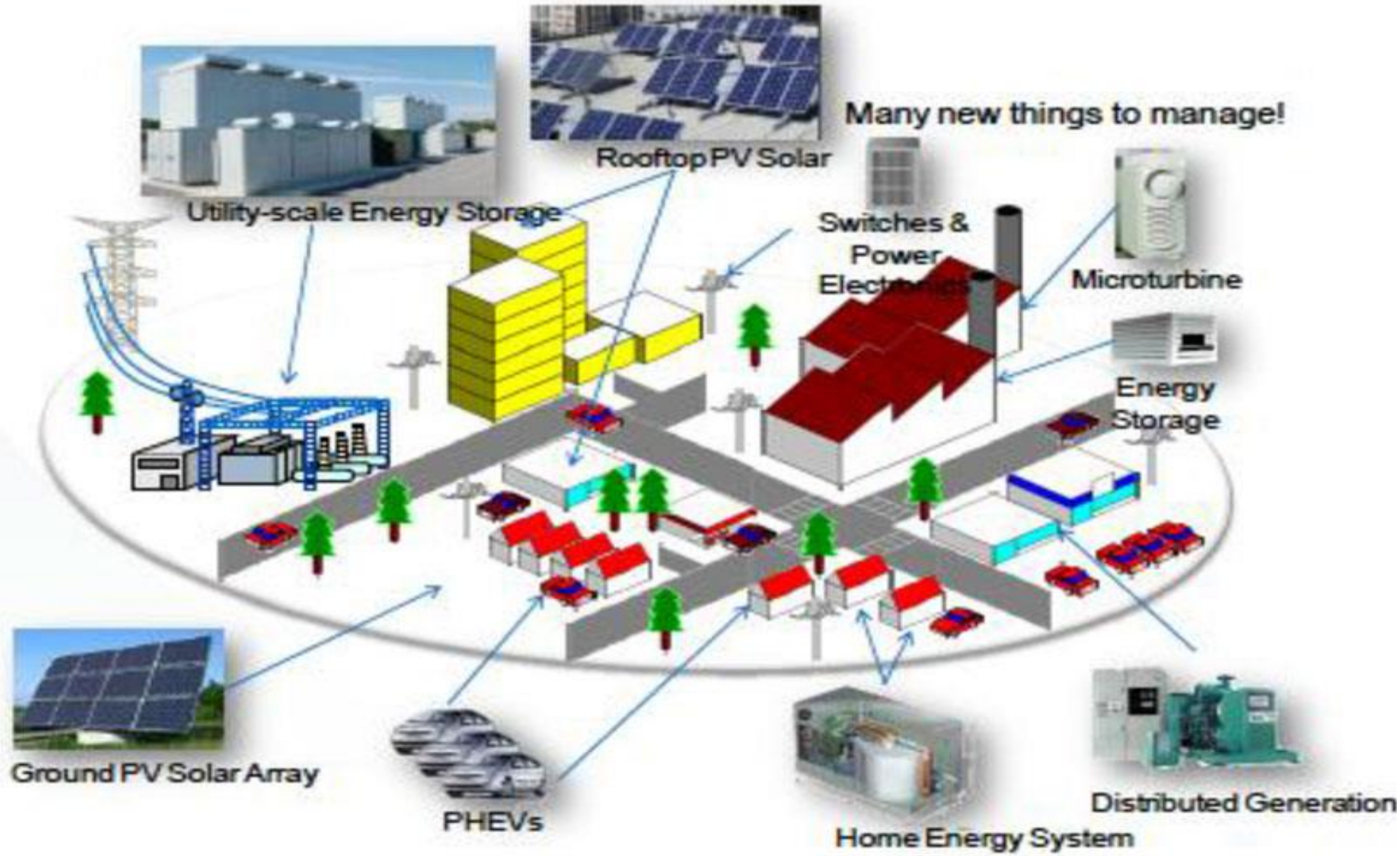
SALIENT μg FEATURES

- **The energy storage devices mainly consist of rechargeable batteries**
- **Their operations are coordinated with the other generation and load resources to help in the supply – demand balance maintenance**
- **Power electronic converters are generally used to provide grid interface of the various distributed energy resources in a μg**

SALIENT μg FEATURES

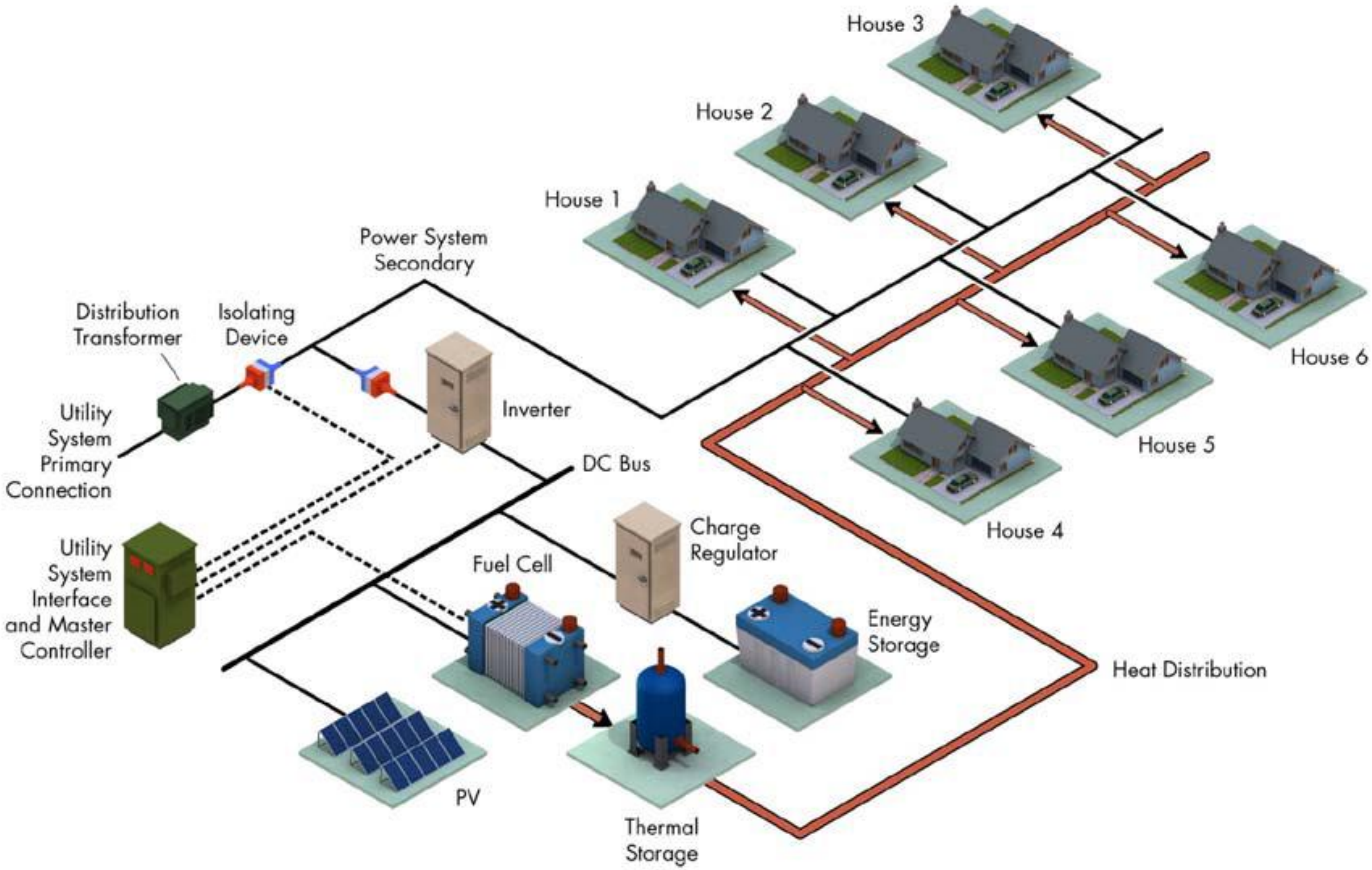
- **The μg loads also get an opportunity to contribute to electricity generation by the deployment of rooftop solar on their own homes**
- **The connection of loads to the local generation may use the utility distribution network or deploy the newly implemented μg wires**

A TYPICAL μg DESIGN



source: http://testgec.us/about-us/technology/

A RESIDENTIAL *μg* DESIGN

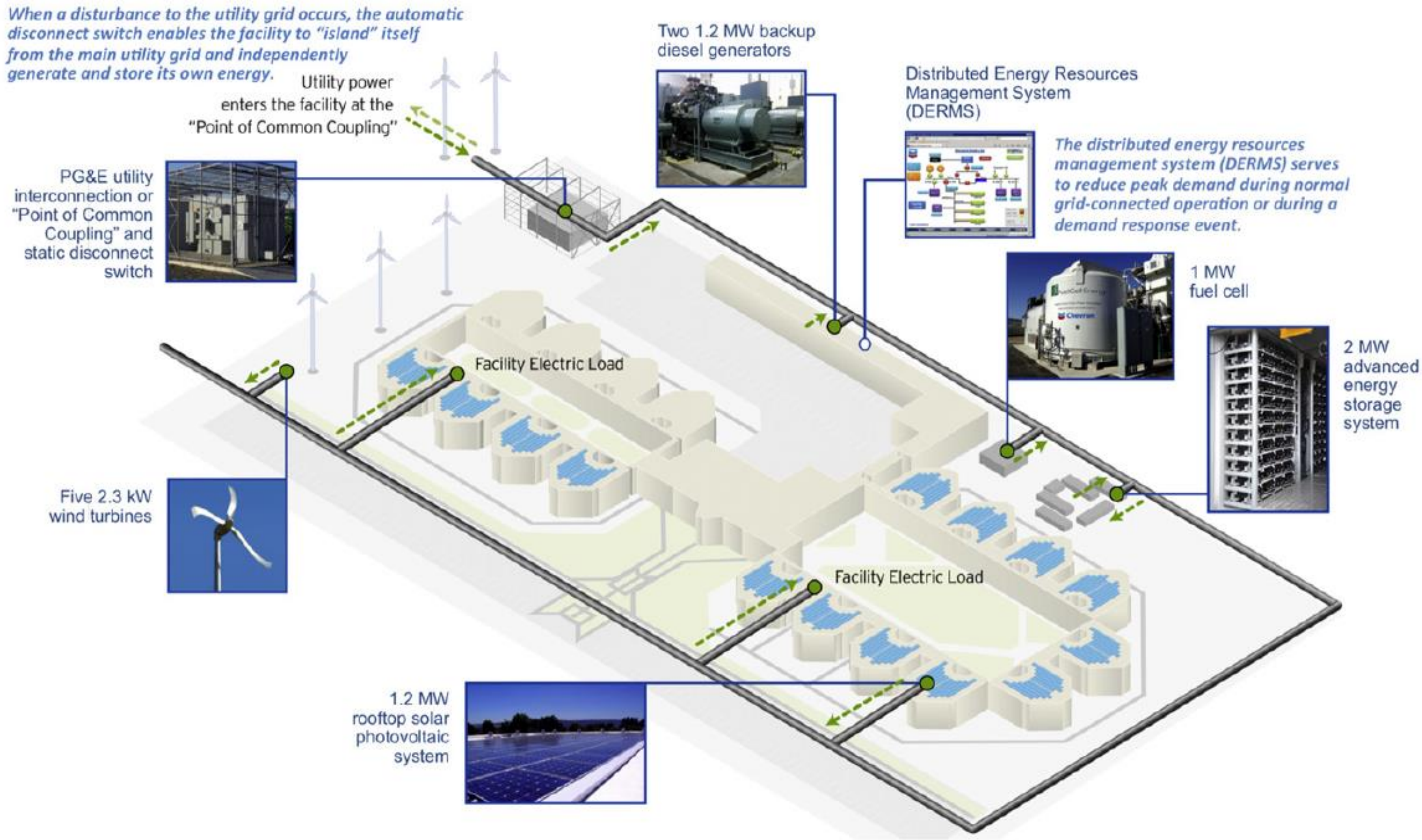


source: EPRI report, Microgrids: A Primer

CRITICAL LOAD : SANTA RITA JAIL

Source : https://der.lbl.gov/

SANTA RITA JAIL LAYOUT

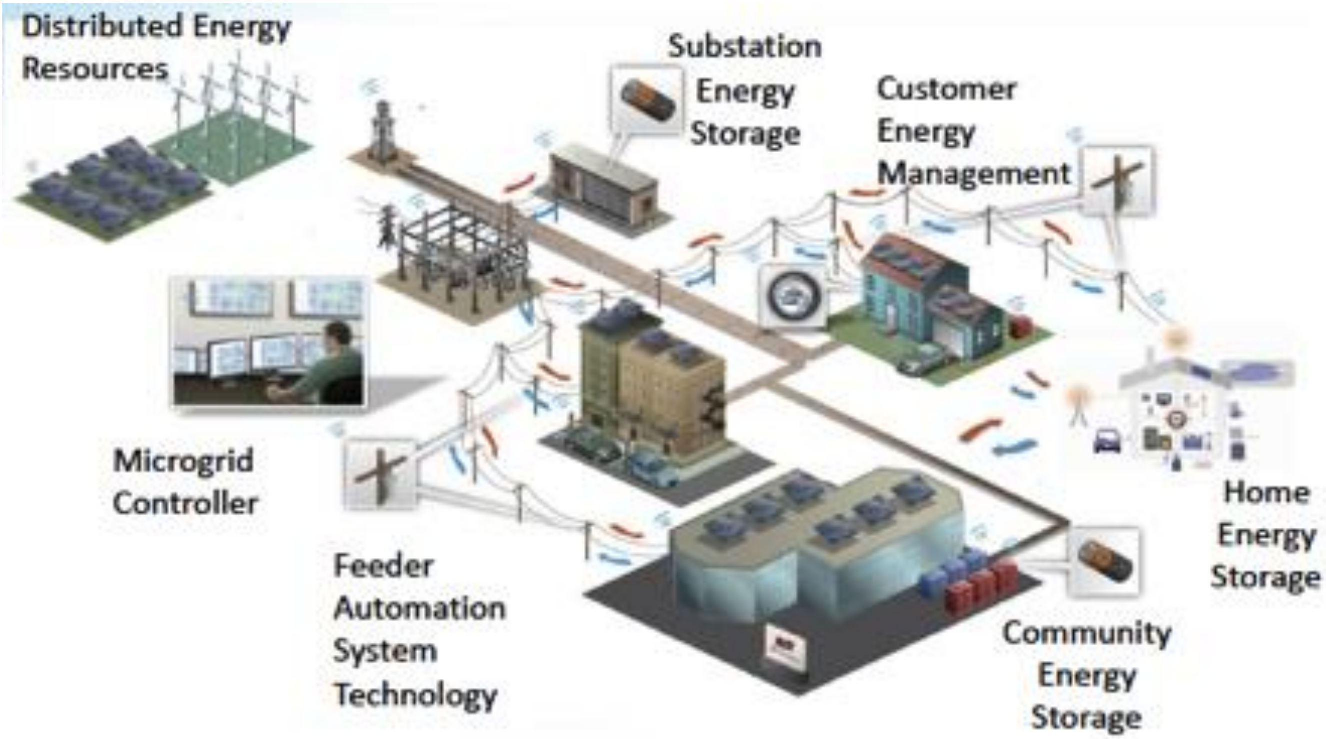


Source : /http://www.sciencedirect.com/science/article/pii/S1040619012002254

SANTA RITA JAIL: μg FEATURES

- Jail is considered to be a critical load and the continuity of electricity supply is a must which is ensured by a μg implementation
- Project has a $1.2–MW$ rooftop solar PV array, $1–MW$ fuel cell and a $2–MW$ energy storage system
- The μg operations alternate between
  - grid-connected mode with power purchases during non peak hours
  - islanded mode with ability to operate autonomously for up to 8 hours

ISOLATED COMMUNITY : BORREGO SPRINGS *μg*



Source : http://www.greenenergycorp.com/borrego-springs-microgrid-project/

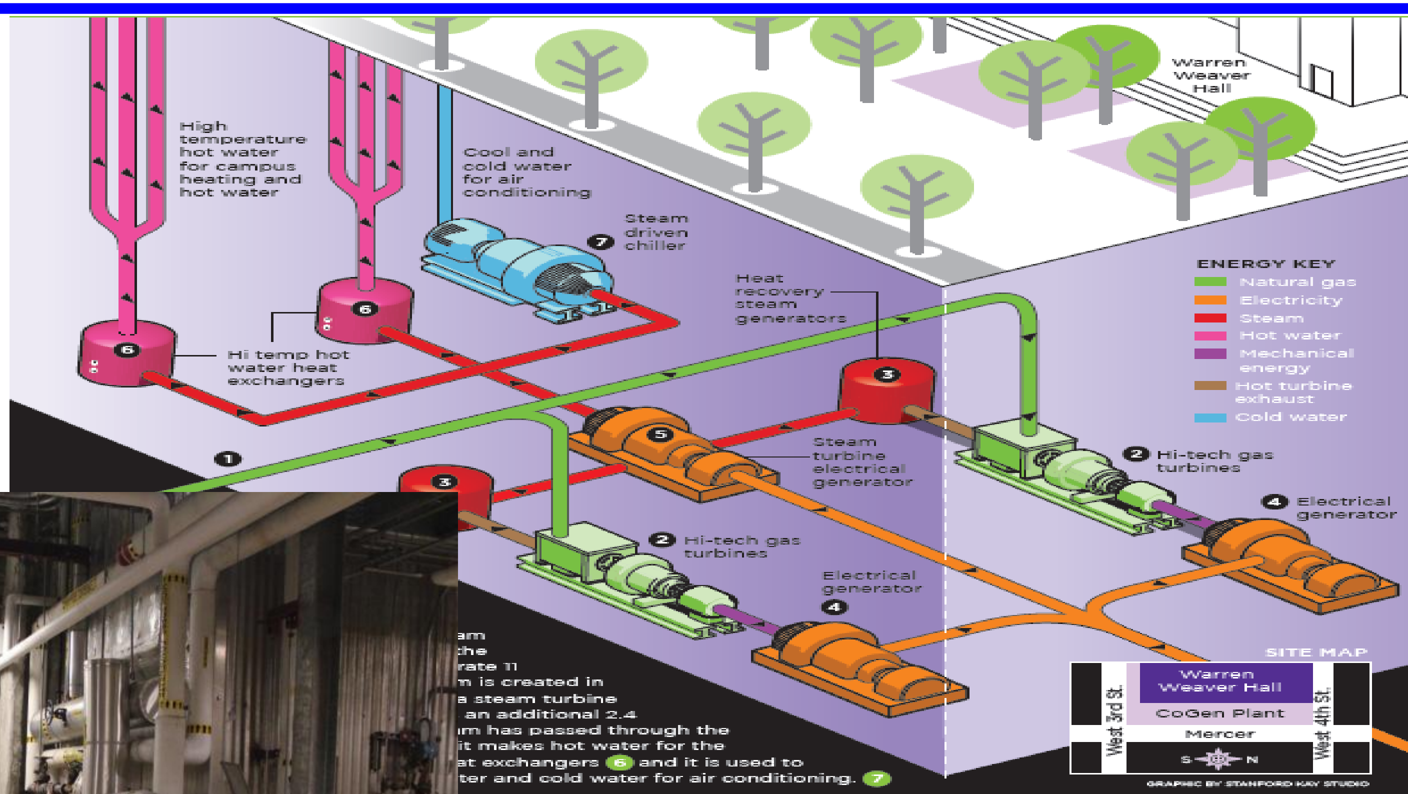
ISOLATED COMMUNITY : BORREGO SPRINGS *μg*

- Borrego Springs is an isolated community fed by a single transmission line
- Any damage to that transmission line may leave a lot of consumers without power, a situation that is avoided by a *μg* implementation by *SDG&E*
- In September 2013, a thunderstorm damaged the only transmission line but within a few hours, 1,060 customers had their power restored automatically due to its *μg* operation

ISOLATED COMMUNITY : BORREGO SPRINGS μg

- The μg remained islanded during the emergency situation as the utility company repaired the damaged poles
- Borrego Springs μg consists of two $1.8\ MW$ diesel generator, about $700\ MW$ of rooftop solar PV and batteries for additional storage
- It is able to serve a peak load of around $4.5\ MW$

NEW YORK UNIVERSITY *μg* UNDER HURRICANE *SANDY*



http://foreignpolicyblogs.com/2011/02/18/trigeneration/

NEW YORK UNIVERSITY *μg* UNDER HURRICANE *SANDY*

- During hurricane *Sandy*, 1.9 *million* people lost power in *NY* city as *Con Ed* had shut down power to prevent any further damage to the generating system and equipment due to facility flooding
- The *NYU μg* demonstrated the resilient nature of the *μg*s by generating electricity during the storm by the help of its newly installed cogeneration plant which didn't flood as it was located in a chamber beneath the ground

NEW YORK UNIVERSITY *μg* UNDER HURRICANE *SANDY*

- ***NYU μg*** **depended upon the underground natural gas grid lines which supplied the fuel to its local gas powered generators to produce electricity**
- **Electricity was then supplied to the buildings which were in close proximity of the generation by its underground distribution network**
- **Built with the purpose to reduce energy costs, *NYU*'s cogeneration plant showcased the most important advantage of a *μg* in maintaining the continuity of supply under an unexpected event**

NEW YORK UNIVERSITY *μg* : OTHER BENEFITS

- The total savings on the annual energy costs due to the *NYU μg* turned out to be a huge *$ 5* to *$ 8 million* per year
- The *NYU μg* also makes use of the waste heat from gas generators for heating purposes
- The *NYU μg* generating resources that replaced the old oil fired generators have drastically reduced *NYU*'s NO_x, SO_2, and CO_2 emissions

BENEFITS

- One of the primary features of the *μg* as seen in the examples is the ability to disconnect from the area utility and continue to provide electricity to its customer during unexpected events
- *μg*s have a smaller demand to manage and hence the control of intermittency of renewable energy generation is easier at a local level through coordination of storage and demand with generation output

BENEFITS

- μgs can help in reducing the line losses to a certain extent with the generators and loads existing within a defined boundary
- μgs can recapture the waste heat from the local generation to use for heating purposes
- μgs can help in reducing the NO_x, SO_2, and CO_2 emissions

BENEFITS

- From the system operator standpoint, a *μg* can serve as:
  - a reliable, dispatchable energy resource
  - an ancillary service resource
  - a load shed resource
  - a consumption resource (to handle over generation)

BENEFITS

- The most important benefit of the *μg* is its lesser dependence on the huge and currently stressed grid and hence it shows increased resiliency against cyber threats by providing better design for security

TRADITIONAL GRID SECURITY

- **Traditionally , power grid automation systems have been physically isolated from the corporate network.**
- **This has been changing, perhaps due to the cost effectiveness of utilization public networks.**
- **Using public networks considerably increases the vulnerability of power grids cyber attacks by increasing the exposure surface of these networks.**

GRID UNDER ATTACK

Component-wise

- Field components like RTU are attacked through remote access.

Protocol-wise

- Using the communication protocols available in the public domain, an intruder can reverse engineer the data acquisition protocols and exploit them.

Topology-wise

- Network topology vulnerability is exploited.
- E.g.. DoS (Denial of Service) attack

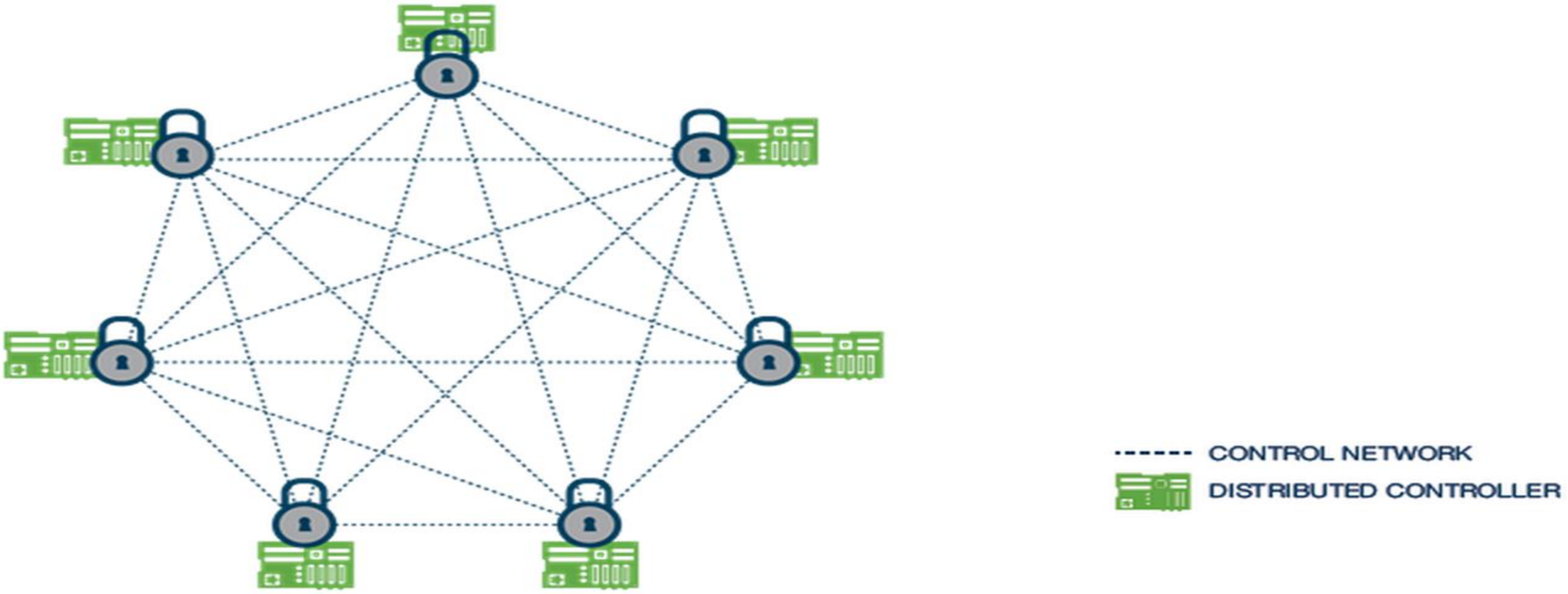
Source: Black Hat

SECURITY IN *μg*

- **Security and Resiliency are the current buzzwords of *μg* projects and for good reason**
- **The Department of Homeland Security's Industrial Control Systems Cyber Emergency Response Team (ICS-CERT) reported that in 2012, attacks on the energy sector represented close to half of the total number of cyber incidents received**
- **Microgrid cyber security starts with the control system architecture**

SECURITY BY DESIGN

Removing a single master controller from the system also removes the single point of failure it represents. Instead, IPERC systems are built with processors located at each Microgrid component, all connected with encrypted communication.



Source: IPERC

ADVANTAGES OF MICROGRID

- **From the software point of view:**
  - **Peer-to-peer architecture**
  - **Encryption of data in transit**
  - **Encryption of data at rest**
  - **Enclaving**
  - **Whitelisting**
  - **Authentication**
  - **Intrusion detection**
  - **Event auditing and cyber alerts**

CONCLUSIONS

- The unexpected weather events, increased electricity needs and potential threat to the cyber security of the grid have raised several questions over the reliability of the current grid
- Hence, a pragmatic solution is seen in the wider-spread implementation of the *μg* concept
- The performance of *NYU μg* during the hurricane *Sandy* is an example of the resilient nature of a *μg* under an extreme event

CONCLUSIONS

- In addition to the resiliency that a μg can provide, it can also provide several other benefits to its consumers inside a μg
- μg technologies are getting better and more cost effective with better control algorithms, efficient energy management systems, reduced costs of renewable and natural gas electricity generation

CONCLUSIONS

- **There are currently 405 microgrid projects that are under development or fully operating as of April 2013, with 219 projects in the *US***
- ***μg*s are considered to be the building blocks of a smart, reliable and a resilient grid which is required in today's scenario**

CONCLUSIONS

- ***μg*s are here to stay, but it would be interesting to see how they are received by the other bodies involved in the current electricity grid**
- **The need right now is to come up with a well defined economic and a technical footprint of a *μg* which does not harm the interests of the existing players in the system**

QUESTIONS TO THINK OVER

- How do you propose a better security architecture to the μg?
- How effective do you think the current design is?
- What kind of communication and control procedures do we need to give to the distribution company to make the best use of the μg?