Technical Considerations Getting to "Microgrid–Ready"

What does it take to put together a well-performing Microgrid?

By: Michael Higginson

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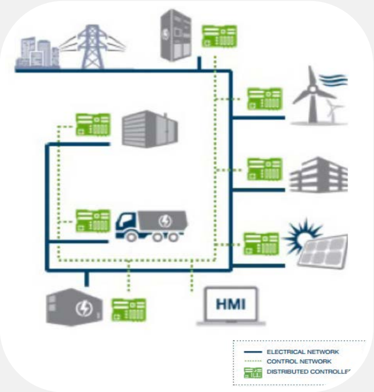
Microgrid Building Blocks

Distributed Energy Resources (DERs)

Switching and Protection Devices

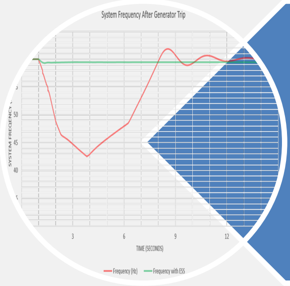


Microgrid Control

Distributed Energy Resources (DERs)

DERs: Considerations

Power and energy capabilities



Response to system events

Paralleling and interconnection limitations

Conventional Generation: Power and Energy Capabilities

Power output

- Minimum output
- Maximum output

Energy

- Fuel availability

Efficiency

- Typically ~30%
- Can be increased to ~80% with CHP

Battery Energy Storage: Power and Energy Capabilities

Power output

- Minimum output (charging)
- Maximum output (discharging)

Energy

- Battery capacity

Efficiency

- 80-90+% round trip efficiency

Renewable Resources:
Power and Energy Capabilities

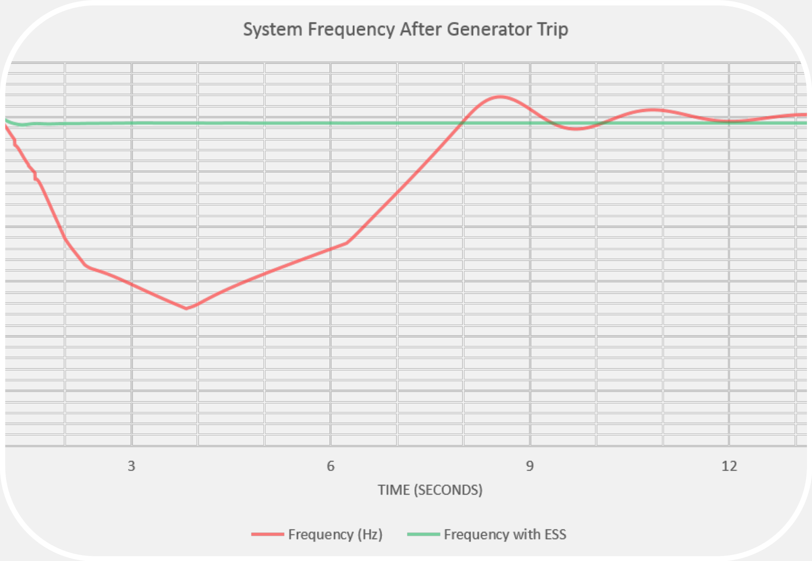
Power output

- Minimum output
- Maximum output

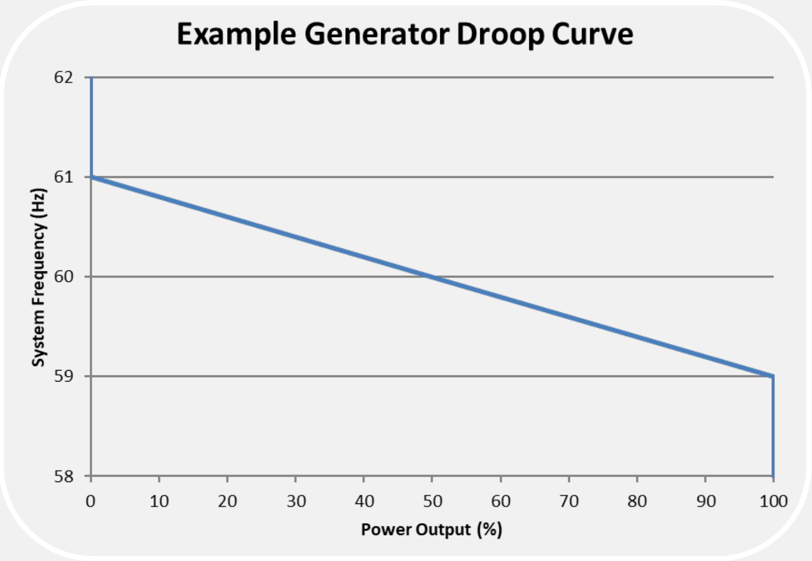
Energy

Intermittency

Generators: Frequency Response



Load Acceptance

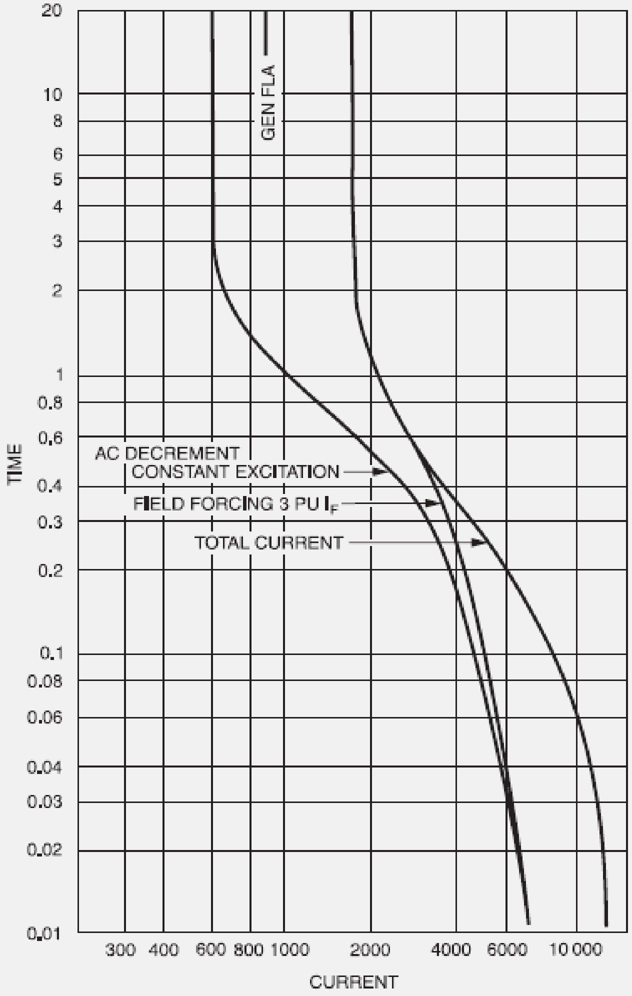


Droop and Isochronous Controls

Generators: Fault Response

Decrement Curves

- Current decreases with time
- Machine will respond to events on utility system



Inverter-Interconnected Resources: Fault Response

Ride-through

- Voltage and frequency tripping

Limited output current

Fast response

Paralleling and Interconnection Considerations

System grounding while islanded

Synchronization

Generator pitch and harmonics

Activity: Select DERs

- Critical load: 20-250 kW
- Evaluate the advantages and disadvantages of each of the following generation options:

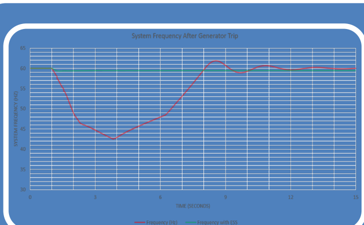
Option 1	Option 2	Option 3	Option 4
250 kW Battery	300 kW Conventional Generator	300 kW Conventional Generator	250 kW Battery
100 kW Solar PV		100 kW Solar PV	300 kW Conventional Generator
			100 kW Solar PV

DERs: Key Takeaway

Distributed energy resources must be carefully selected weighing advantages and disadvantages

Power and energy capabilities

- Ensuring sufficient capacity
- Optimizing DER performance under expected load



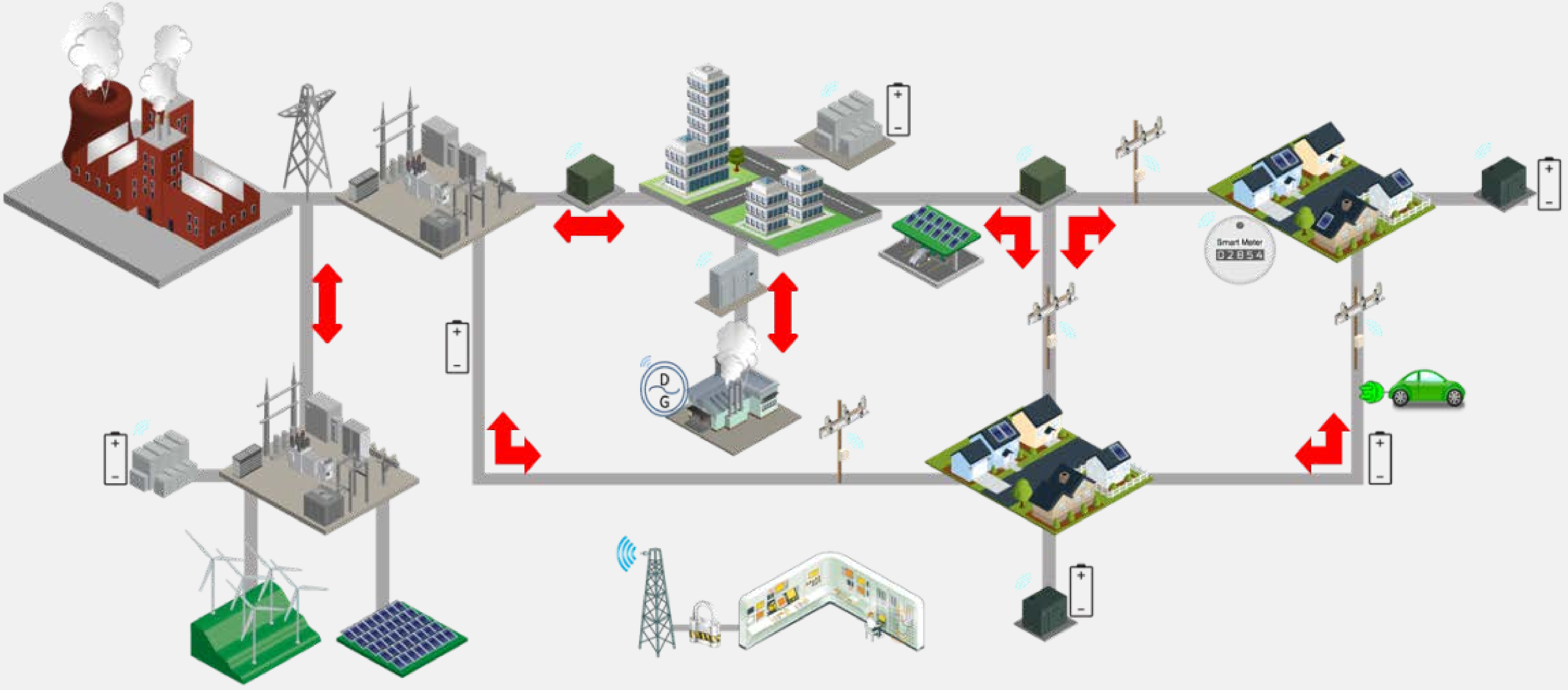
Response to system events

- Accepting load
- Local and remote fault response

Paralleling and interconnection limitations

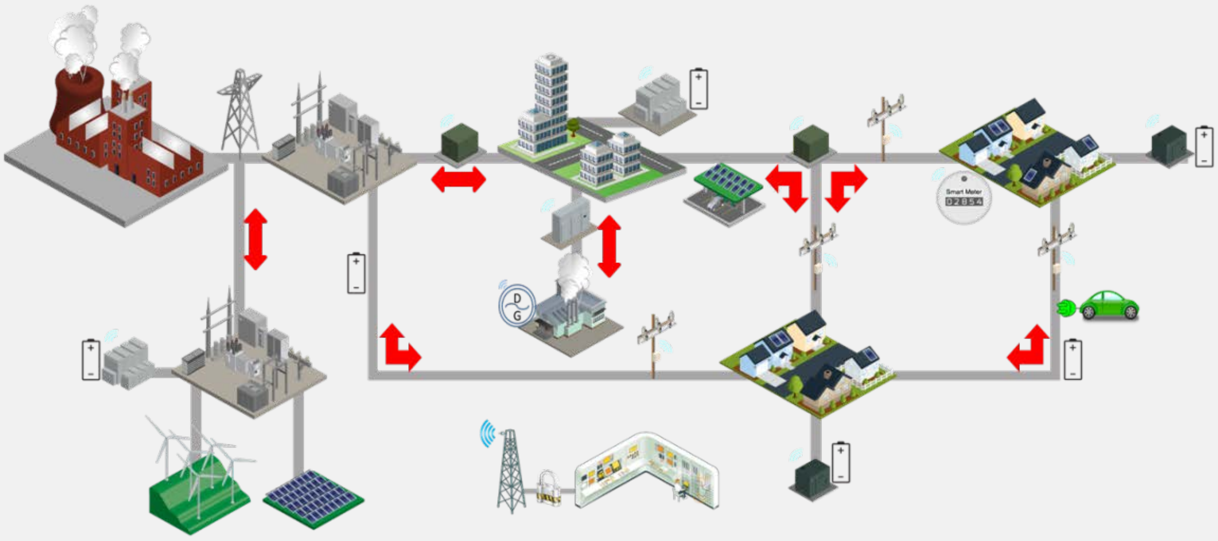
- Can resources parallel?

Microgrid Switching and Protection



Microgrid Protection Challenges

- System topology changes:
  - Complex power flow, instead of from remote generation to load
  - Opening and closing switches
  - DER fault behavior



Microgrid Protection: Key Ideas

Differentiate between load, inrush, and fault current through all scenarios

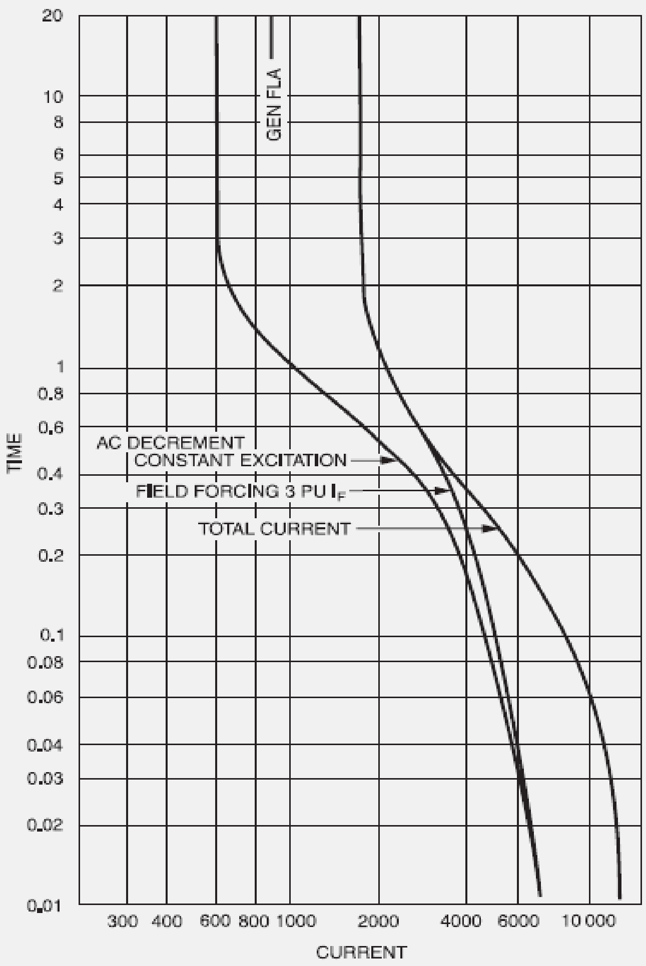
Directionality in microgrid protection is necessary to achieve selective coordination

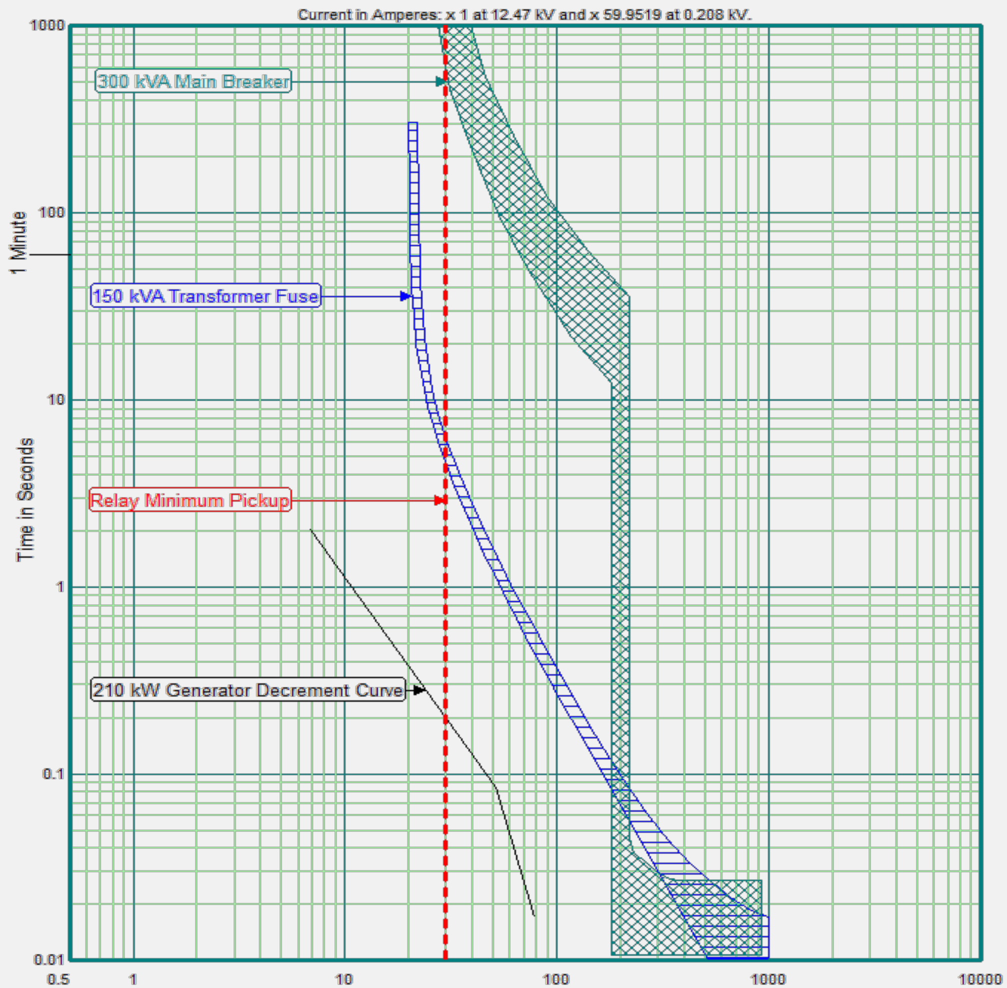
Coordinate with downstream overcurrent devices

Fault Current from Inverters

- Limited fault current availability
- Ride-through capabilities

Generator Fault Decrement



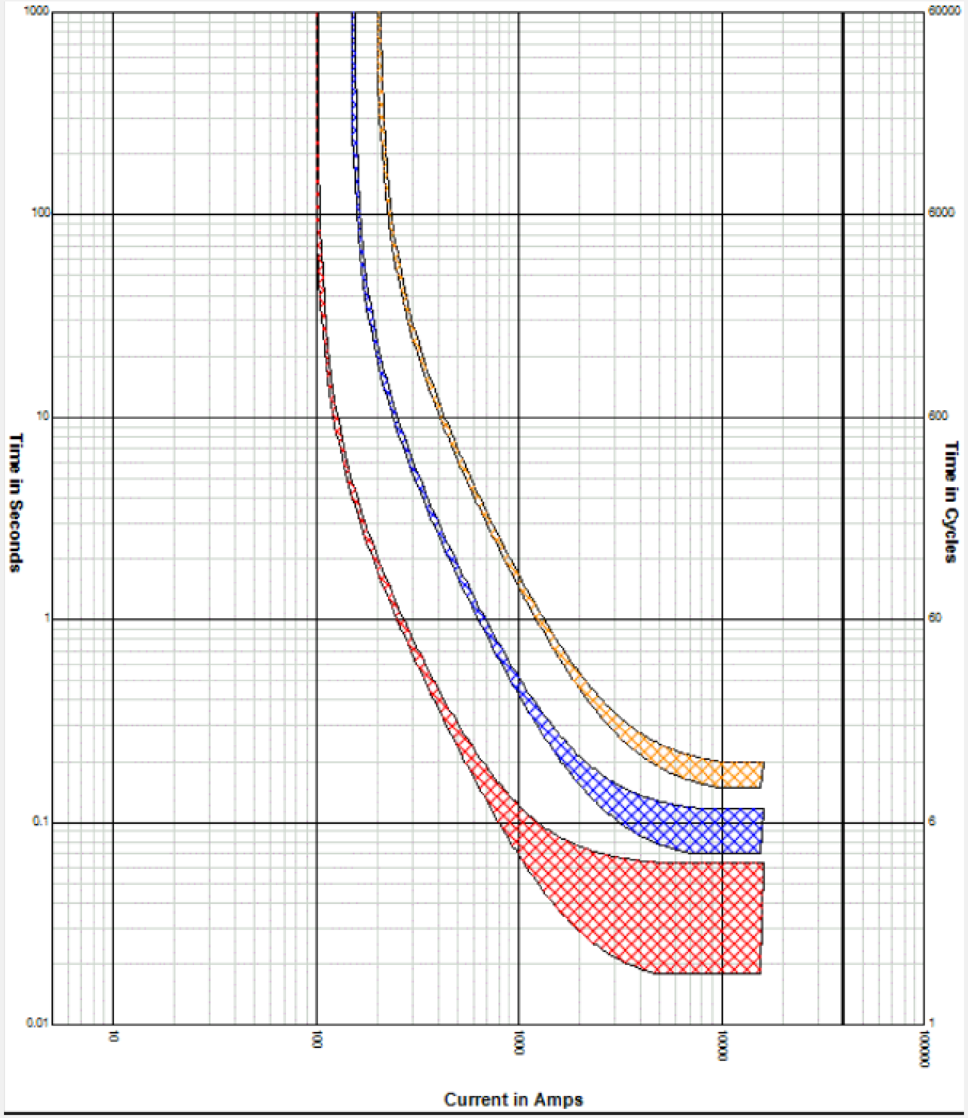


Example Microgrid Scenarios

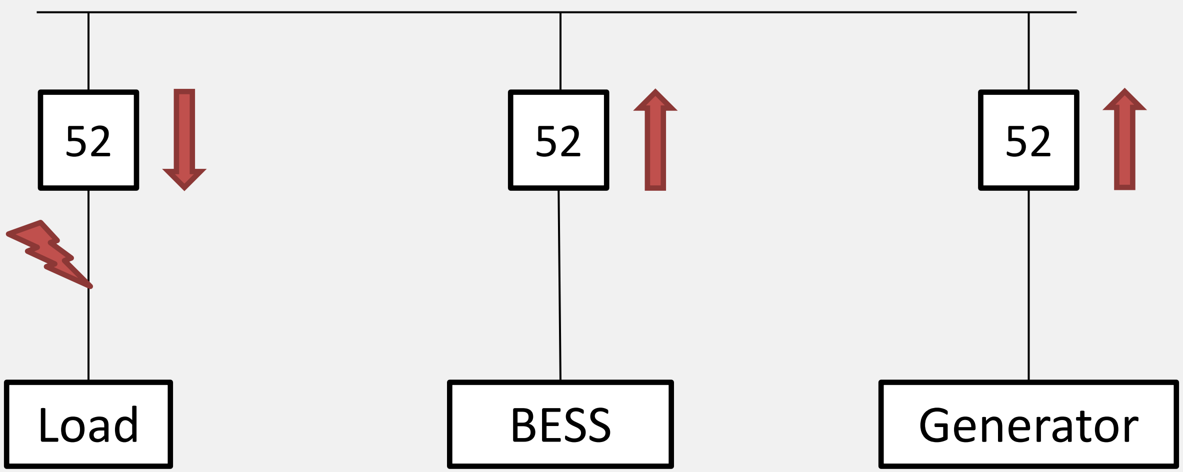
- 12.47 kV System
- 250 kW BESS
- 1 MW Natural Gas Generator
- Renewable resources

Grid-Tied Fault Current (kA)	Islanded Max Fault Current (kA)	Islanded Min Fault Current (kA)	Max Load Current (kA)
5.0	0.5	0.02	0.05

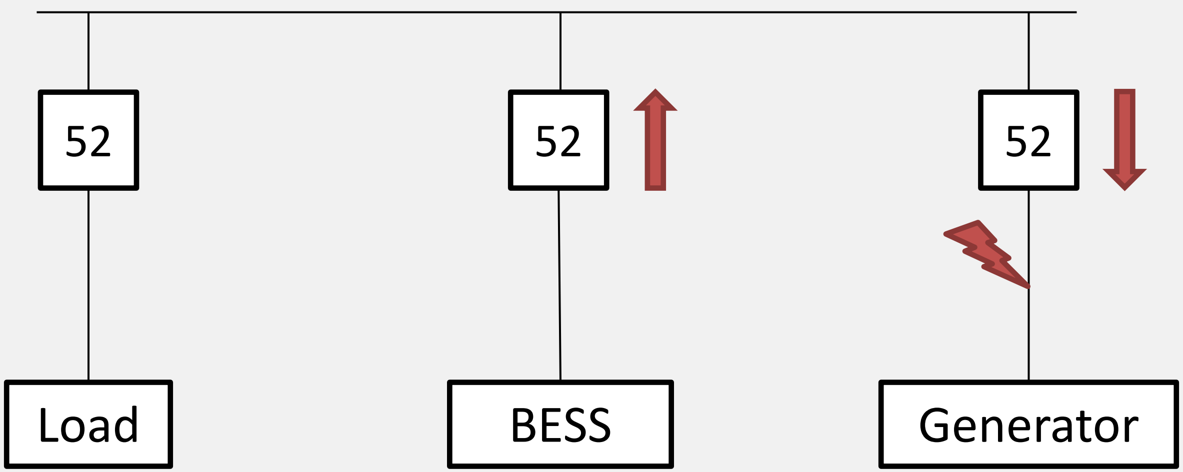
Need for Protection Directionality



Example Fault Scenario



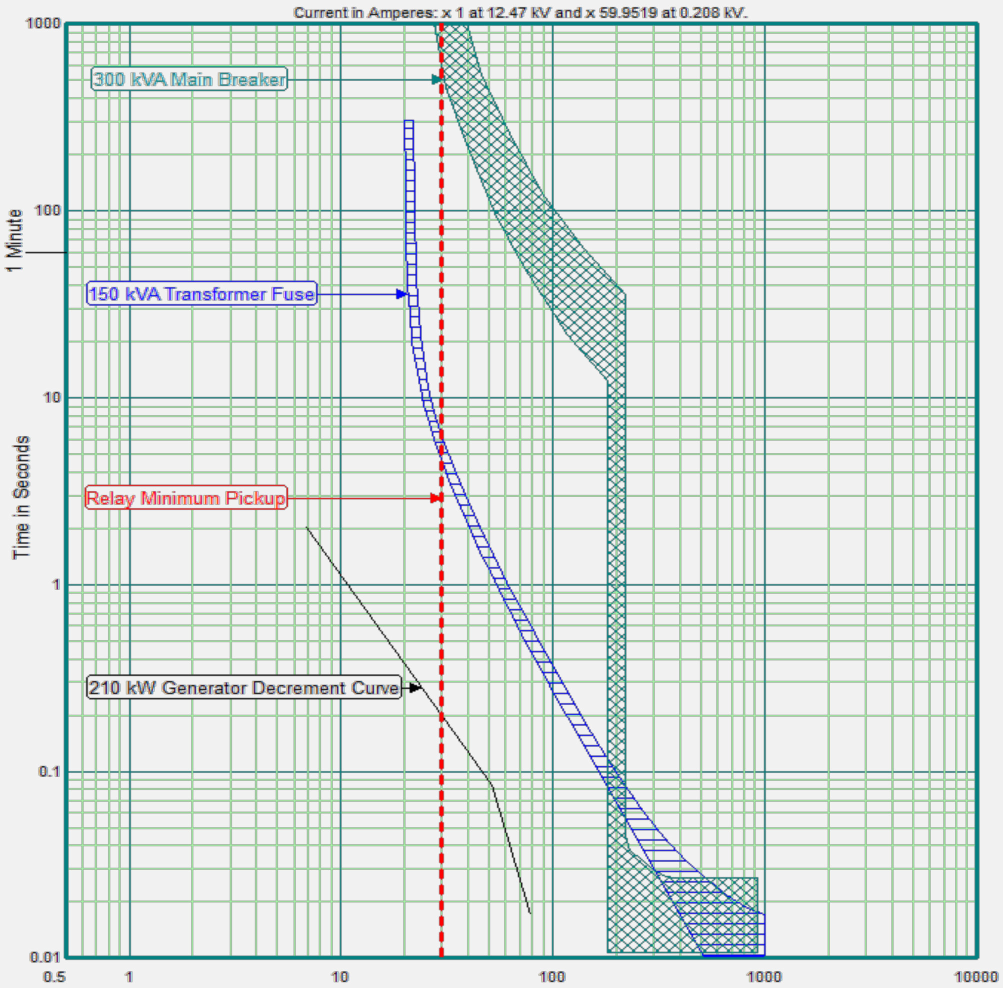
Example Fault Scenario



Challenges in Identifying Direction

- Delay in relay
- System frequency changes
- Inverter output waveforms
- CT saturation

Coordinating with Existing Devices



- Existing devices on system are likely overcurrent protection
  - Lateral and transformer fuses
  - Low-voltage breakers
  - Generator + inverter breakers

- Some devices may not operate while islanded

- If selected carefully, breakers can be coordinated for many fault scenarios

Microgrid Protection: Key Takeaways

Differentiate between load, inrush, and fault current through all scenarios

Directionality in microgrid protection is necessary to achieve selective coordination

Coordinate with downstream overcurrent devices

Microgrid Control: Hierarchy

Control Level	Temporal Requirement	Typical Functions	Control Components
Tertiary	Minutes	• Forecasting • Advanced Optimization • Modeling	Software
Secondary	Seconds	• SCADA • Load Control • Generation Control	Hardware/Software
Primary	Microseconds to Milliseconds	• Switching Logic • Protection	• Inverter Controllers • Generator Governor and Exciter • Protection Relays

Microgrid Control: Architecture

SINGLE CENTRAL CONTROL

DISTRIBUTED CONTROLS

Microgrid Control: Cybersecurity

Cybersecurity is needed in microgrids

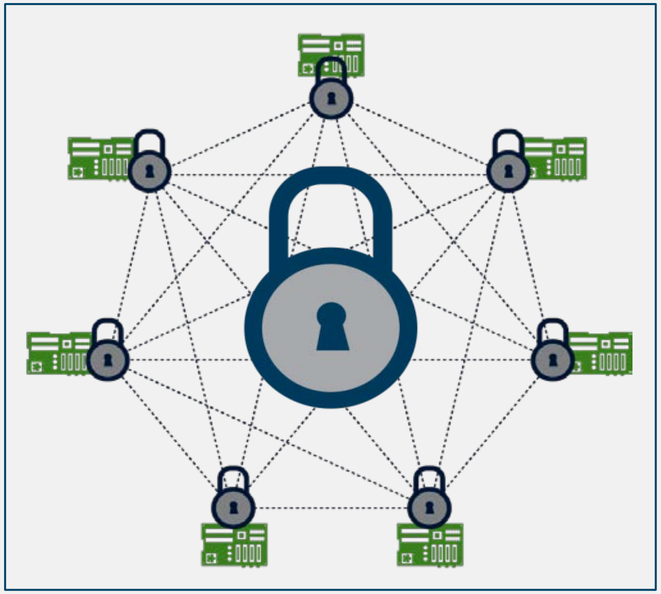
Primary Guidelines

NIST 800-52, Security and Privacy for Federal Information Systems

NIST IR 7628, Guidelines for Smart Grid Cybersecurity

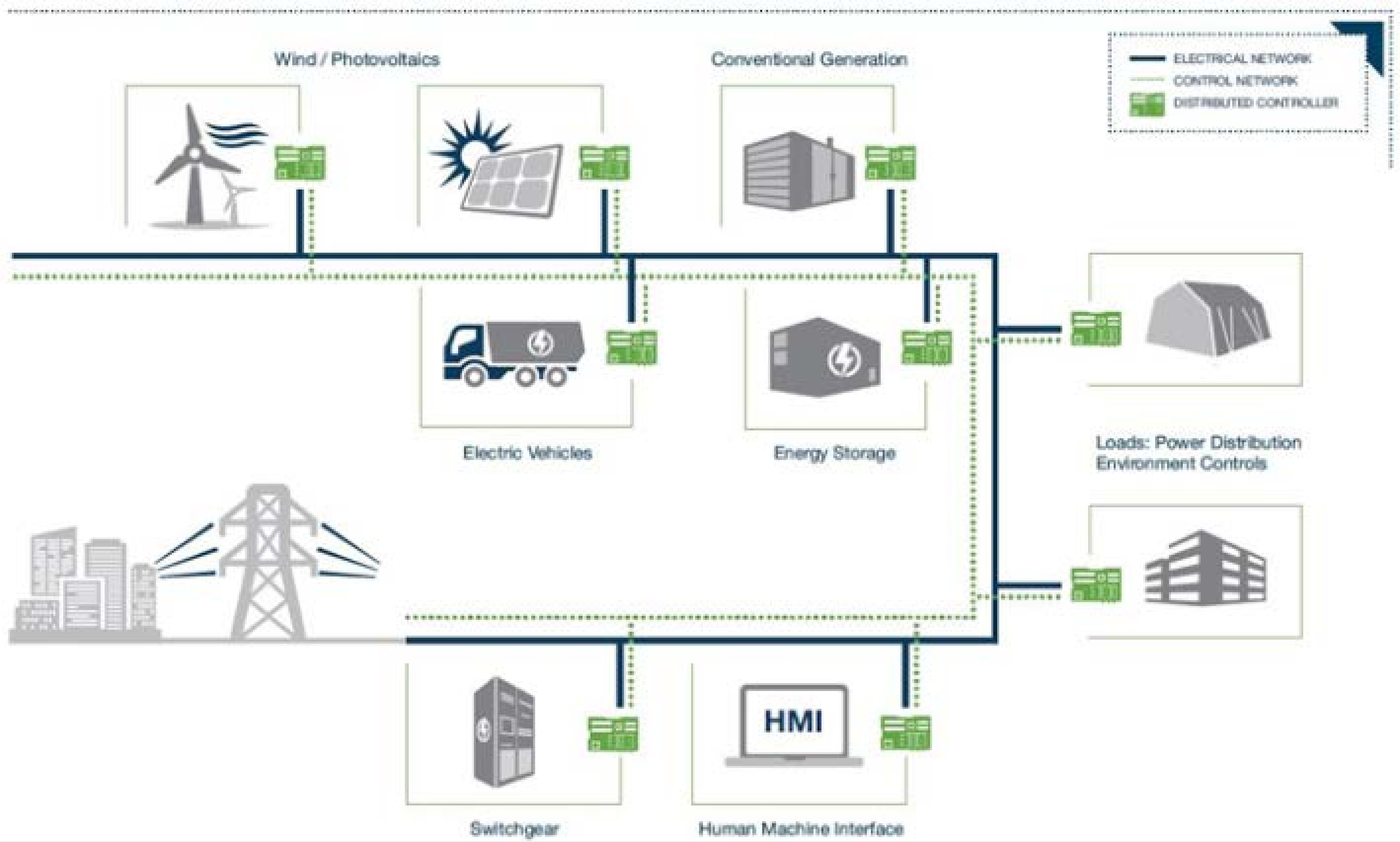
NERC CIP v5, Critical Infrastructure Protection

NIST 800-53, Risk Management Framework



Microgrid Control: Key Takeaway

The microgrid controller is an important part of the microgrid. Getting it wrong can leave your customers in the dark.



Conclusions

Distributed energy resources must be carefully selected weighing advantages and disadvantages

Effective microgrid protection involves use of sophisticated communication-assisted schemes and adaptive relay settings

The microgrid controller is an important part of the microgrid. Getting it wrong can leave your customers in the dark.

Questions

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Contact Us

microgrid@sandc.com