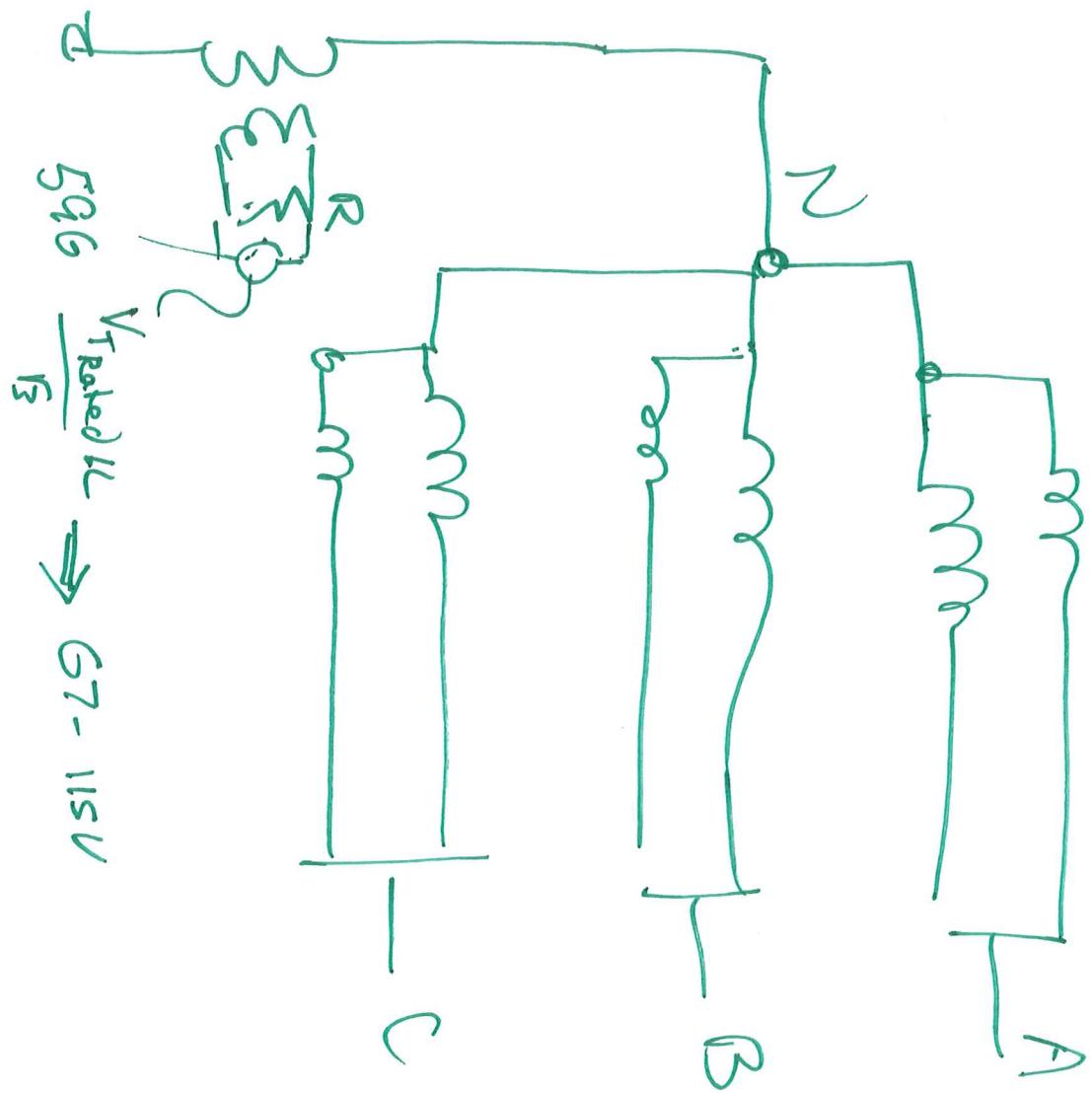


ECE 526

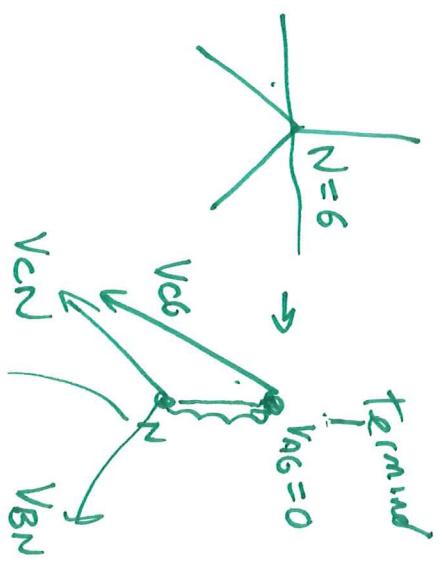
PROTECTION OF  
POWER SYSTEMS II

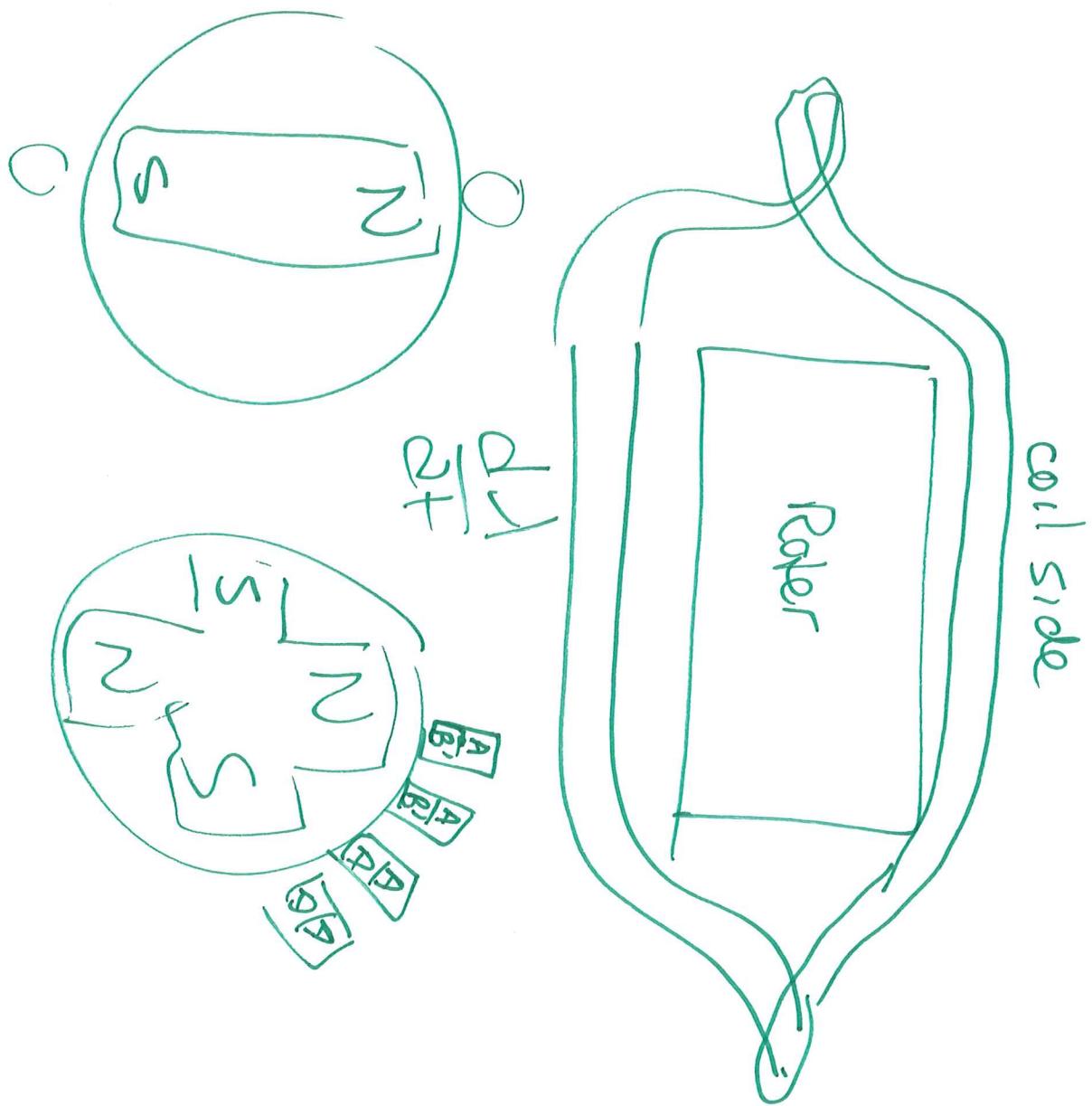
SESSION no. 25

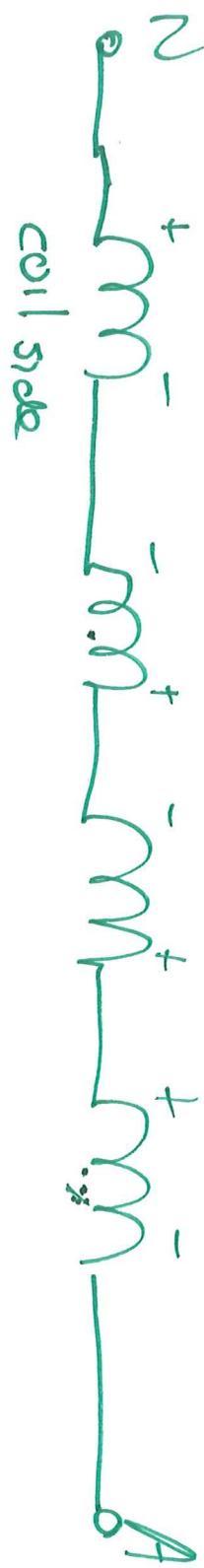


$$5Q_6 \frac{V_{T_{rated}}}{R} \rightarrow 67 - 115V$$

$$V_{NG} = -V_{A6_{\text{rate}}}$$

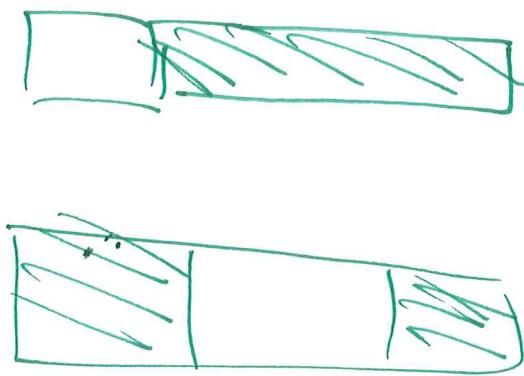




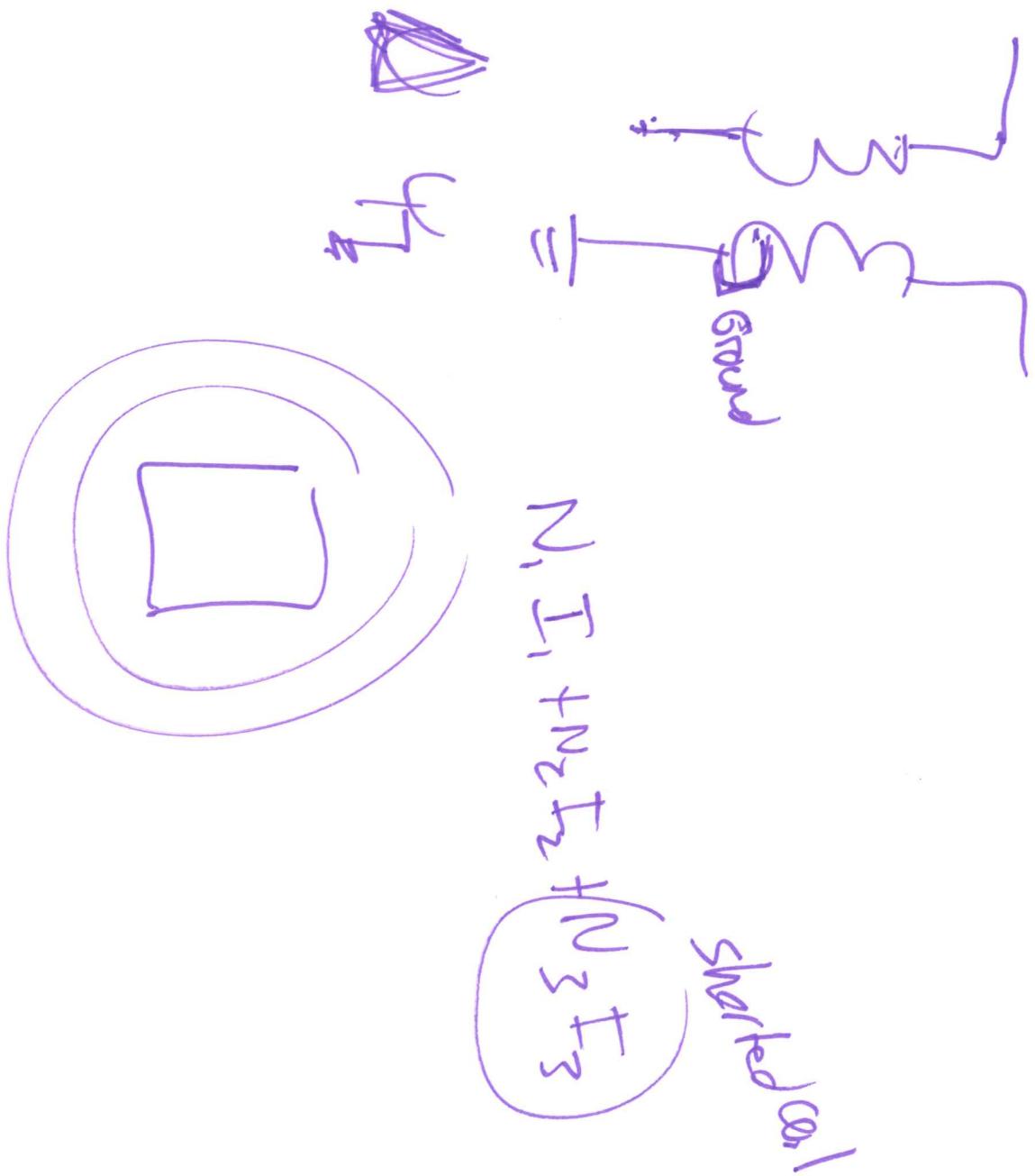


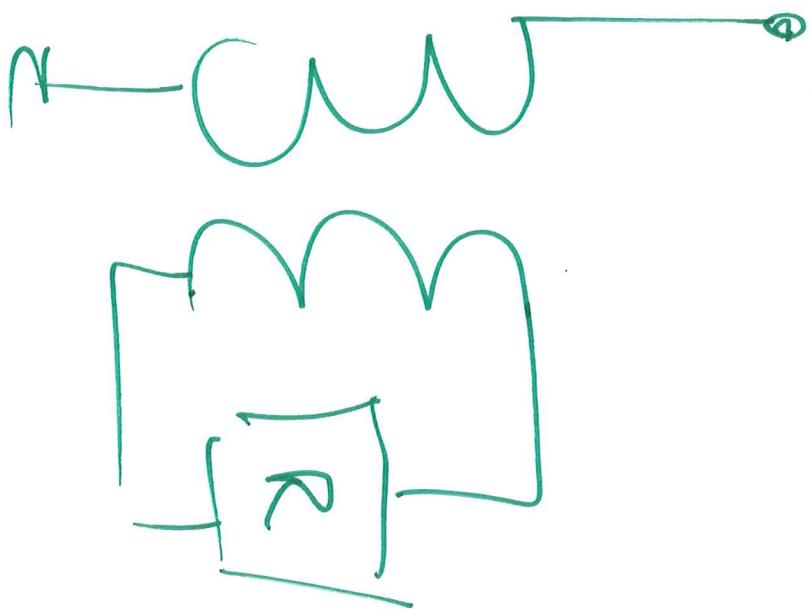
3rd

596



Injection method





$$3R_G = X_{co}$$

- If you know  
all parasitic  
capacitances

- Winding  
- Buswork

- if not

- If don't know it well
- limit SLC cases

Current to 2014

# Distributed Generation Impacts

$U_I$

## Typical Distribution Systems

ECE526

Lecture 25

- Passive
  - » System distributes power to loads
  - » Unidirectional power flow
- Overcurrent relaying
  - » Coordinated with fuses
- Voltage regulation fairly simple
  - » Controlled at substation

Distributed Generation

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connected distribution system

wind PV

$U_I$

## Distributed Generation Protection

ECE526

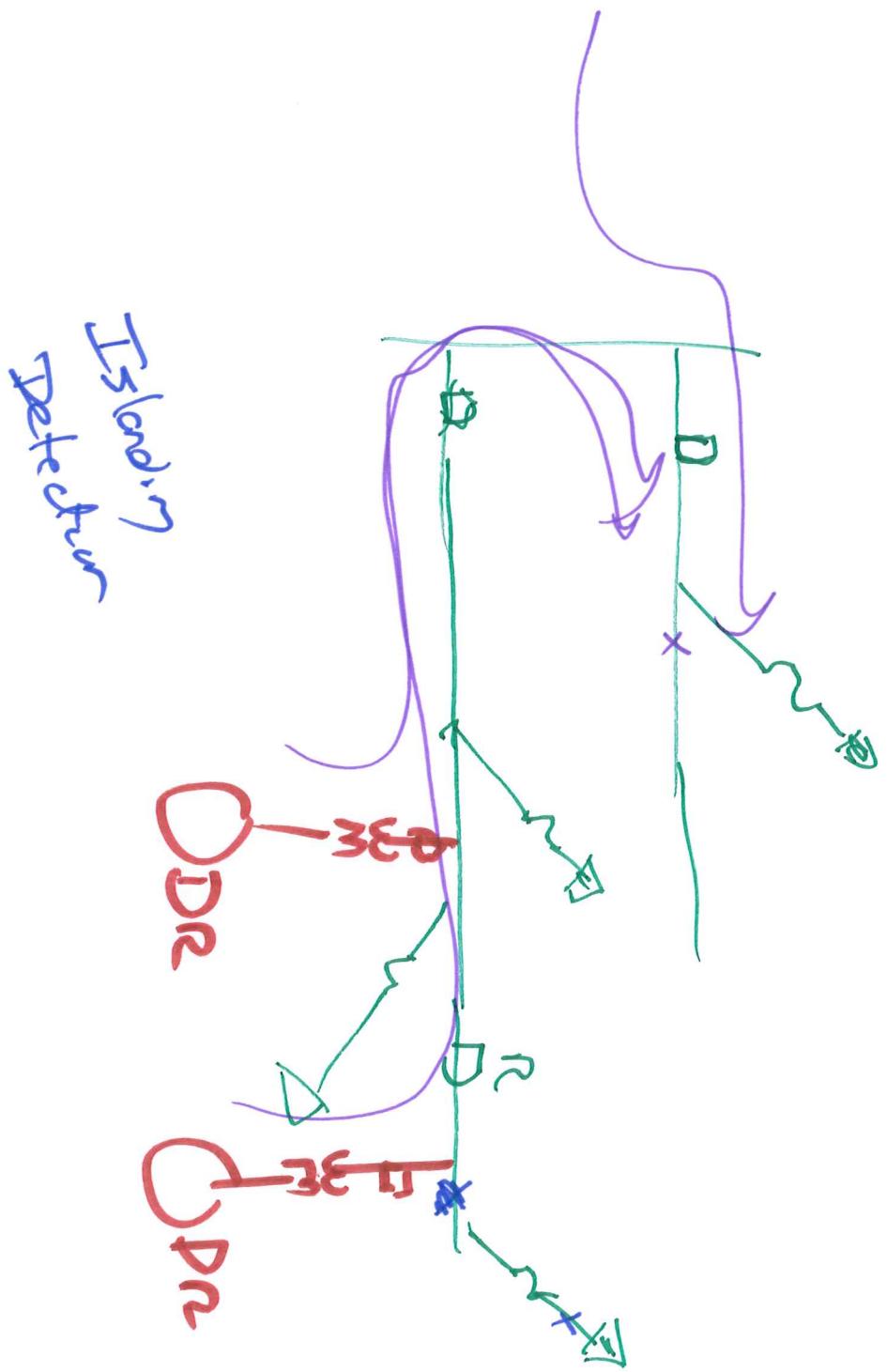
Lecture 25

- What is DG (or DR)?
  - » Synchronous generators
  - » Induction generators
  - » Power electronically coupled generators
  - » Connected to distribution circuit
  - » Typically less than 5MVA (some bigger approaching 10MVA)
  - » Supply owners load, not rest of circuit
- Connection similar to a load

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- Storage - Batteries



LZS 9/13

$U_I$  Protection Impacts

ECE526  
Lecture 25

- Addition voltage source not provided from substation
  - » Fault current source
  - » Backfeed to other circuits
  - » Impact voltage regulation
- Restoration of feeder after outage
- Power quality

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$U_I$  IEEE Standards

ECE526  
Lecture 25

- IEEE 1547-2003: Standard for Interconnecting Distributed Resources with Electrical Systems
  - » Amendment 1, 2014
- 1547.1: Conformance test procedures
- 1547.2: Application Guide for 1547
- 1547.3: Guide for monitoring, information exchange and control

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*microgrid*

$U_I$  IEEE Standards ECE526  
Lecture 25

- 1547.4 Guide for design, operation and integration of DR Island Systems
- 1547.6: Interconnecting Distributed Resources with Electric Power Systems Distribution Secondary Networks
- 1547.7: Conducting DR Impact Studies
- 1547.8 (draft): Supplemental support for implementation strategies for expanded use of IEEE 1547

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$U_I$  Protection Considerations ECE526  
Lecture 25

- IEEE 1547-2003: Standard for Interconnecting Distributed Resources with Electrical Systems
  - » Defines protection at PCC/POI, not generator
  - » Disconnect for voltages outside of range
  - » Disconnect for frequencies out of range
  - » Stay disconnected until feeder restored

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*point of common coupling*  
*point of interconnect*

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## Protection Considerations

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- IEEE 1547-2003: continued
  - » Voltage magnitude fluctuation on synchronization < 5%
  - » Detect unintentional islanding
  - » DG doesn't cause overvoltages
  - » DG doesn't cause miscoordination of protection
  - » Disconnect for faults on feeder

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## Utility perspective

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- C • Protect system from DG
- 51P/51G impacts
- Coordinate with DG protection for facility faults
- C • Transfer trip (if necessary—more likely with higher ratings)
- Don't reclose with DG connected

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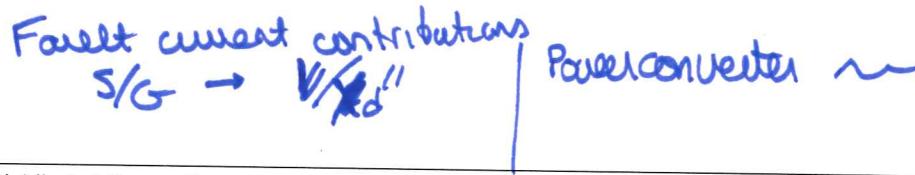
$U_I$ 

## Utility perspective: Back feed issues

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- Downstream loads see larger currents
- Transfer trip to avoid having it feed faults
- Directional protection
- Communication aided protection



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const current  
~120% 1 I<sub>rated</sub>  
- unity p.f.  
- pos sequence  
(if 3Ø)

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## DG owner perspective

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- Protect generator from grid
- Stay connected while meeting IEEE 1547
- Disconnect from utility for system level disturbances and supply on site loads
- Minimum set of standard generator protection

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## 1547 requirements

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- Sense VLL on feeder side of PCC/POI
  - » Overvoltage (59)
  - » Undervoltage (27)
    - Specific clearing time
- Disconnect for frequencies out of range
  - » 810 and 81U

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## 1547 requirements

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- Stay disconnected until voltage on feeder between 88% and 110%
  - » And frequency 59.3-60.5 Hz
  - » Both for 5 minutes
- Detect unintentional island
  - » Disconnect within 2 sec
- Difficult as DG gets large relative to load
  - Rate of change of voltage (ROCOV)

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- Rate of change of frequency (ROCOF)

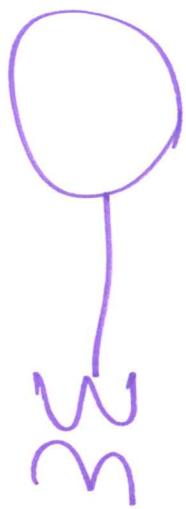
Typical table in Standard

Abnormal Eng function	Default		Range Adjustability	
	$f_{req}$	char time	$f_{req}$ (Hz)	clear time (max)
UF1	<57	0.16	56-60	10
UF2	<59.5	2	56-60	300
OF1	>60.5	2	60-64	300
OF2	>62	0.16	60-64	10

Annex to IS47 in 2014

Transformer connections...

3P DG



No standard connection

$\Delta Y_2$   
 $\Delta Y$   
 $\Delta \Delta$   
 $\Delta \Delta$

Feeder protection  
Needs to know  
which is used