A 13.8-kV 4.75-MVA Microgrid Laboratory Test Bed

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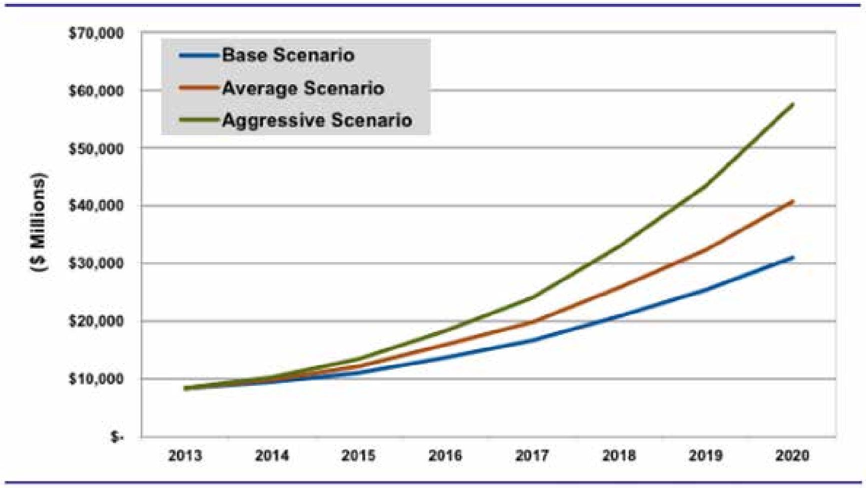
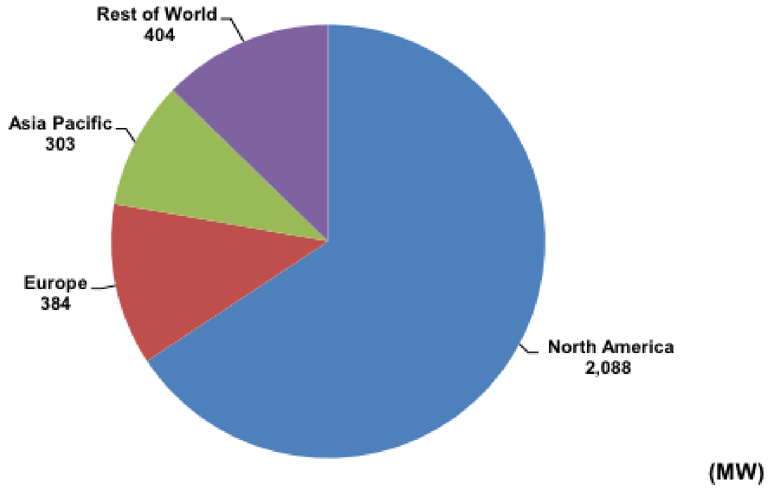
Outline

- Introduction
- UA Microgrid Vision
- Test Bed System
- Purposes of the Test Bed
- Hardware Experimental Results
- Conclusions and Future Work

Microgrid Market



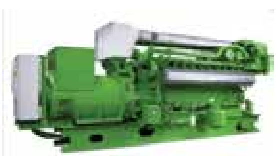
(Source: Navigant Research)



(Source: Pike Research)

Background and Motivation

- Integration of distributed generation (DG)
- Improve energy efficiencies and reduce emissions
- Reduce load outages





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IEEE Guide for Design, Operation, and Integration of Distributed Resource Island Systems with Electric Power Systems (IEEE Std 1547.4™-2011)

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UA Microgrid Vision

- Integration of distributed generation (DG) with power electronic interfaces – in the MVA range

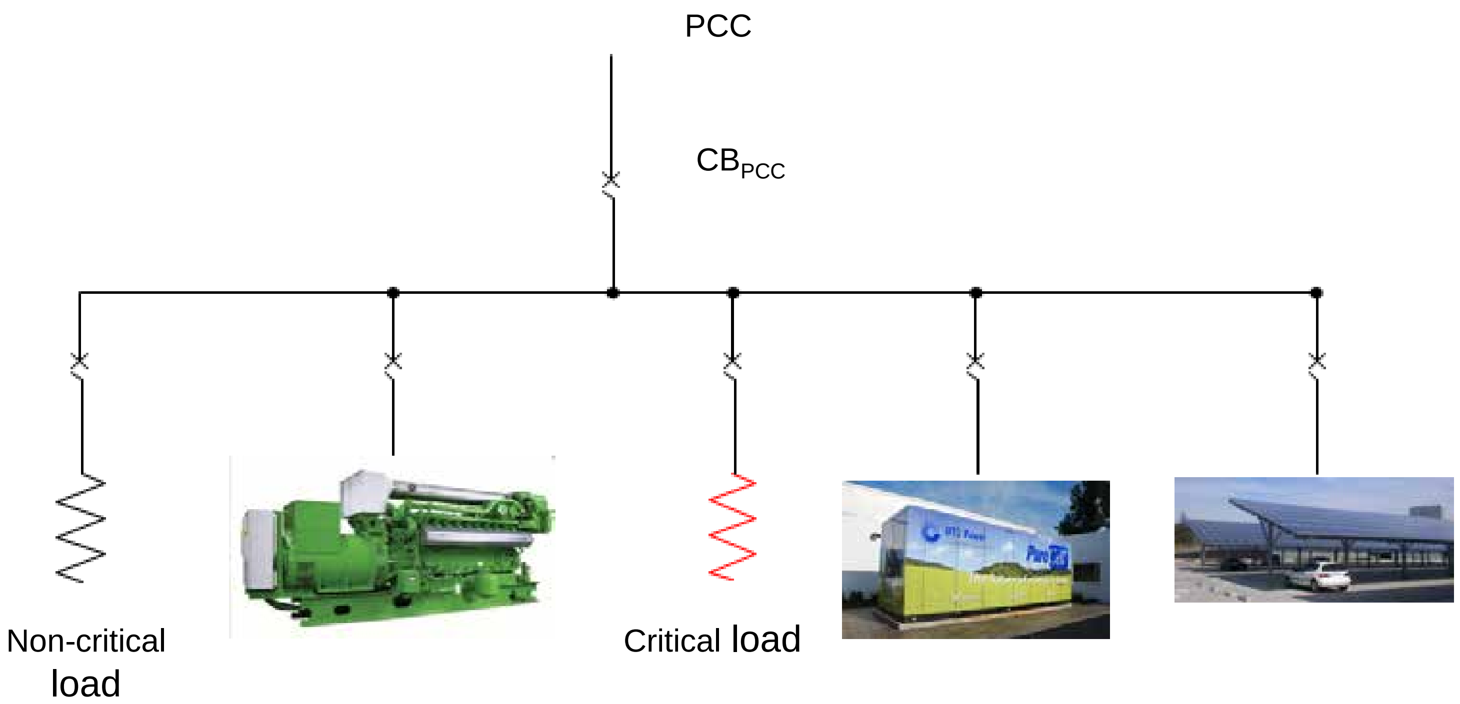
(Fuel cell source: DOE)

(CHP source: Romelectro)

(PV source: Wikipedia)

UA Microgrid Vision

- Integration of distributed generation (DG) with power electronic interfaces– in the MVA range
- Grid (islanded mode and grid-connected mode)



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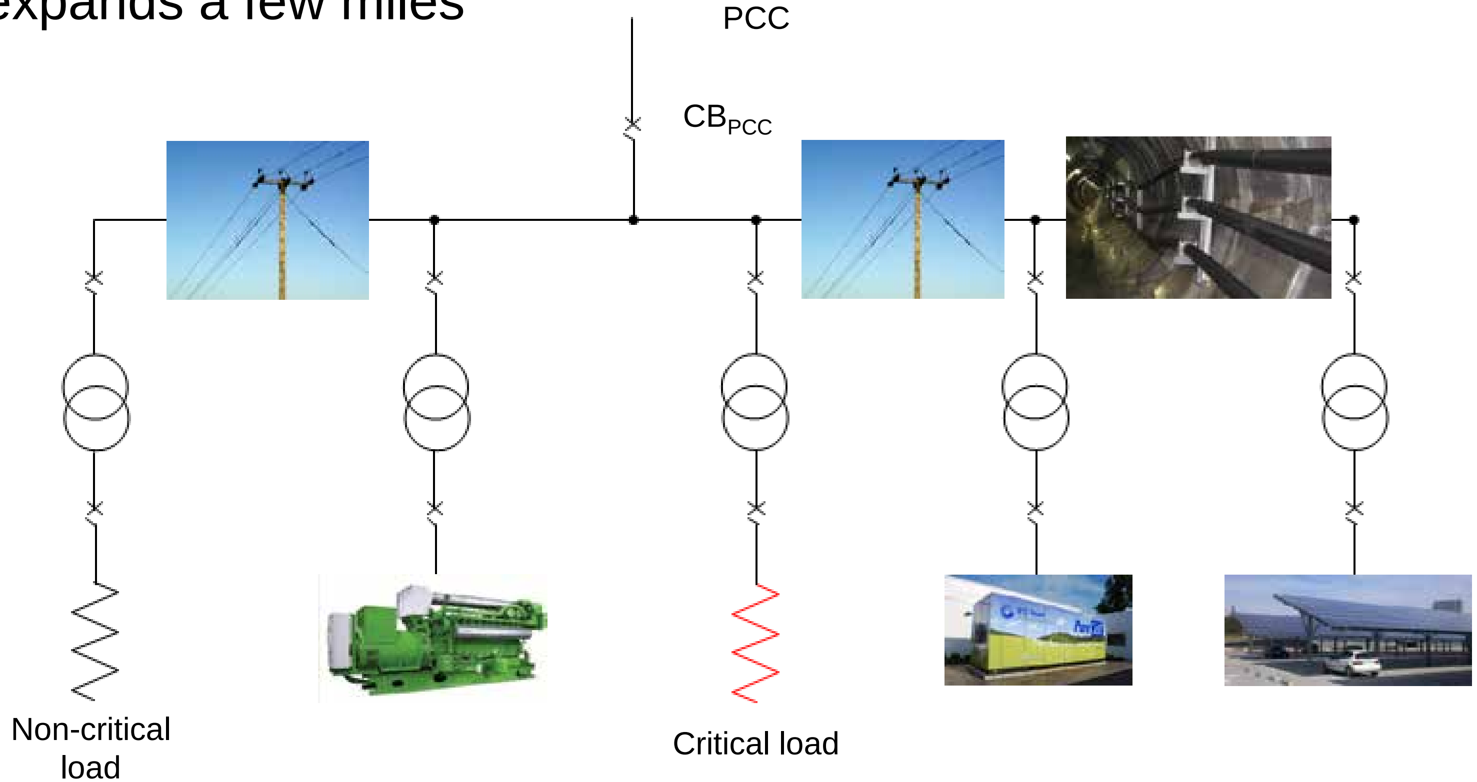
UA Microgrid Vision

- Integration of distributed generation (DG) with power electronic interfaces– in the MVA range
- Grid (islanded mode and grid-connected mode)
- It expands a few miles



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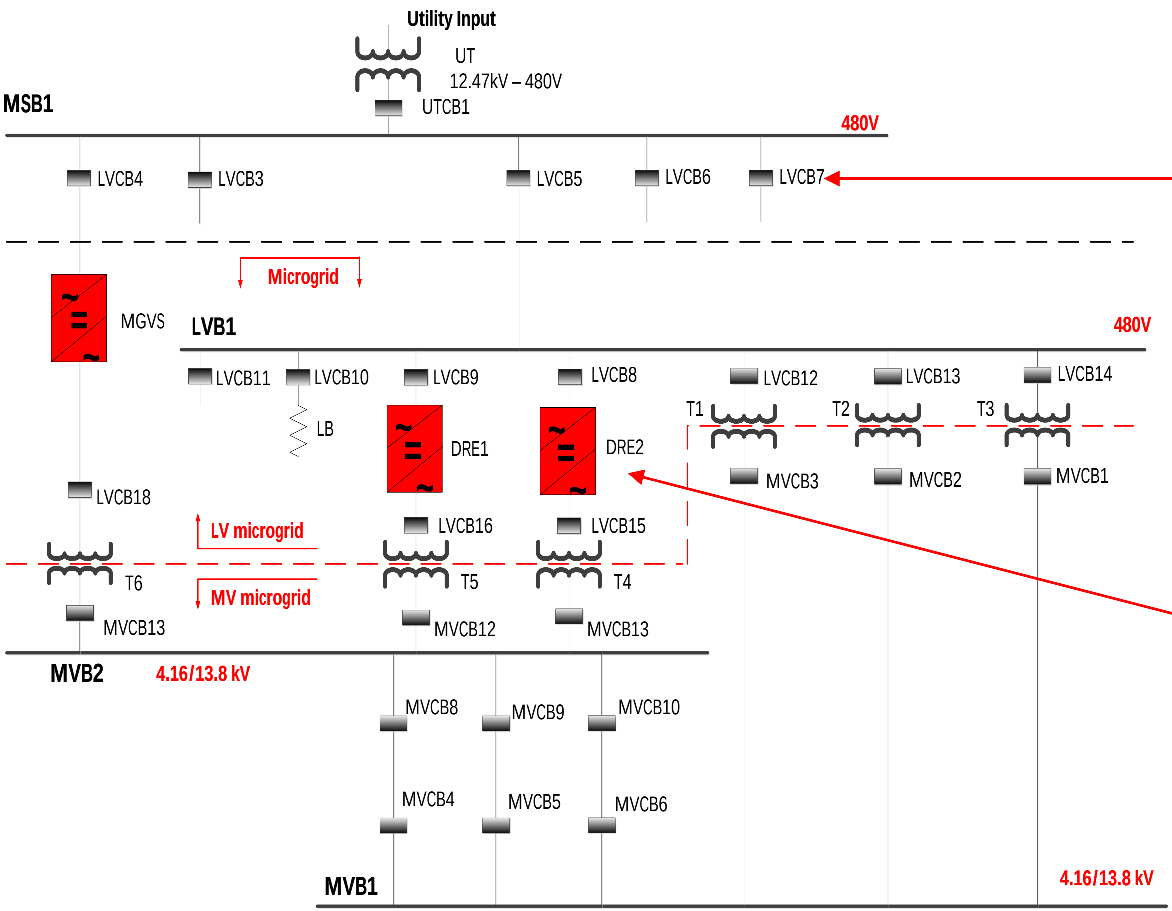
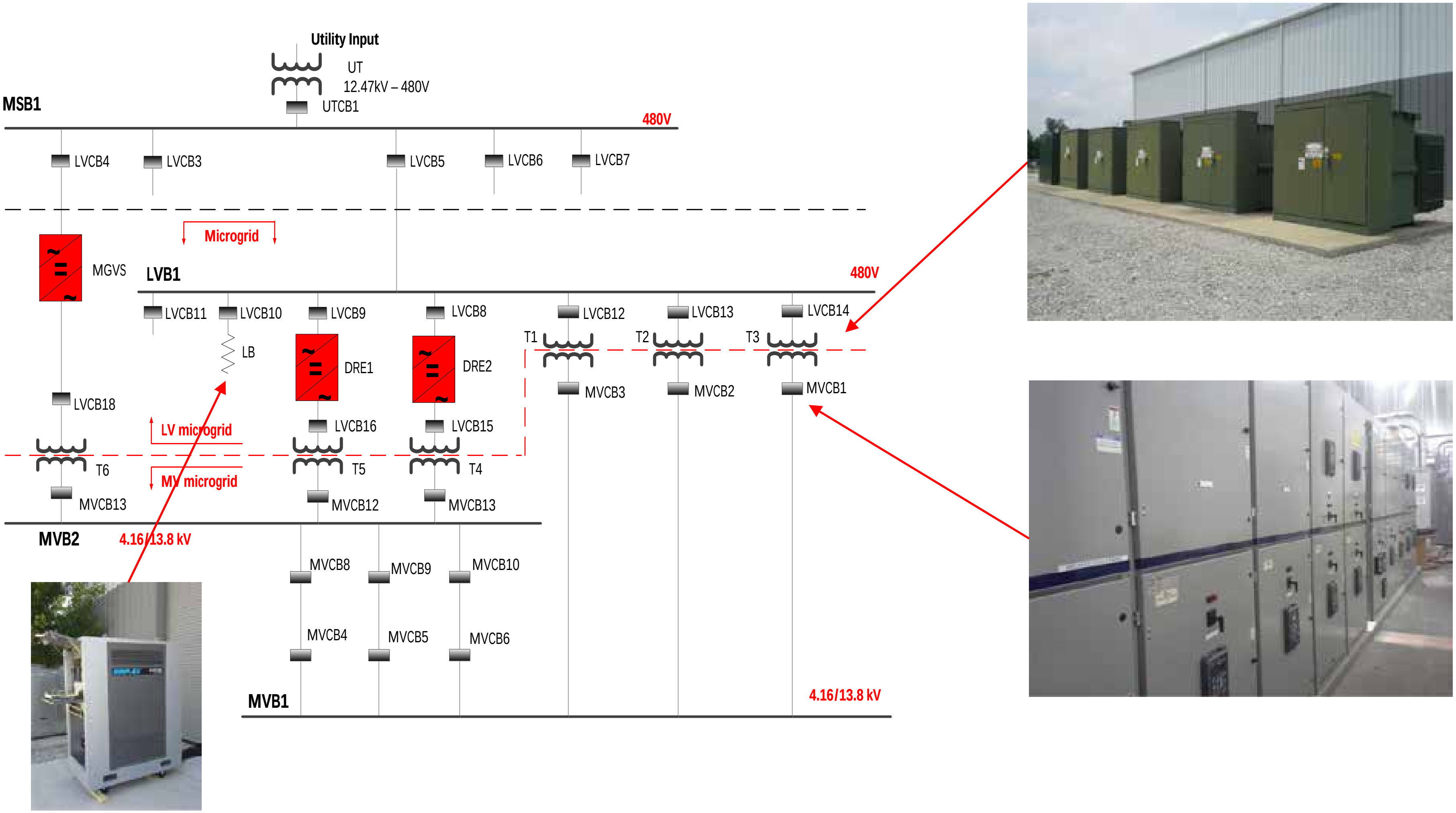
Microgrid Test Bed One-line Diagram

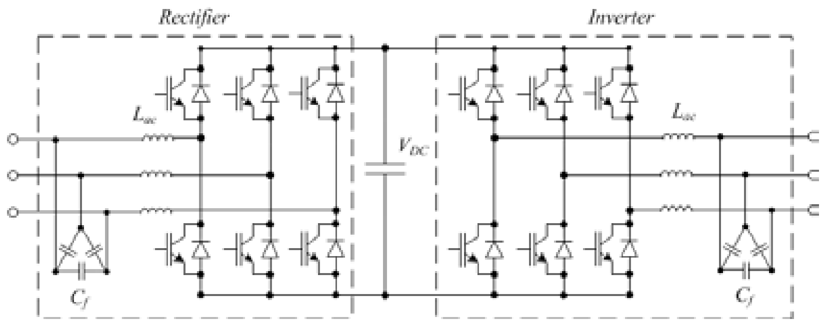


Microgrid Test Bed One-line Diagram

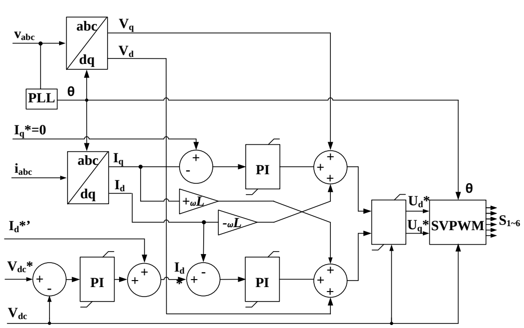


Power Electronic Interfaces

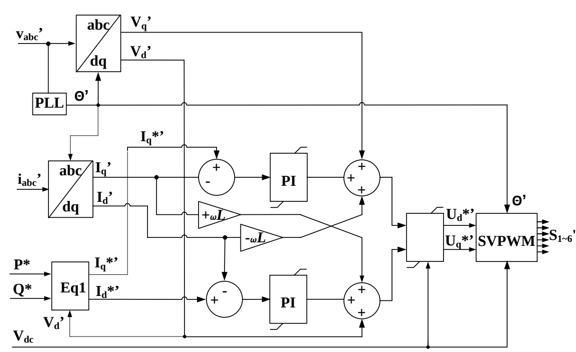
- **Topology of DG emulator**
- **Basic control algorithms**



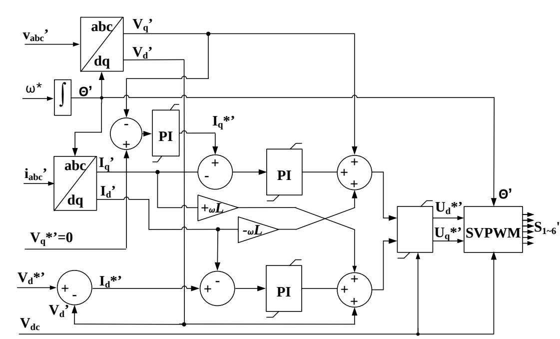
Parameter		Nominal Value
MGVS rated power	S_{MGVS}	0.75 MVA
DRE1 rated power	S_{DRE}	2 MVA
MGVS IGBT swiching frequency	$f_{sw\text{-}MGVS}$	8 kHz
DRE1 IGBT swiching frequency	$f_{sw\text{-}DRE}$	4 kHz
MGVS ac inductor	$L_{ac\text{-}MGVS}$	110 μH (0.135 p.u.)
DRE1 ac inductor	$L_{ac\text{-}DRE}$	20 μH (0.065 p.u.)
MGVS ac capacitor	$C_{f\text{-}MGVS}$	3× 1920 μF
DRE1 ac capacitor	$C_{f\text{-}DRE}$	3× 768 μF
DC link capacitor	C_{DC}	46.2 mF
Rated ac voltage	v_{ac}	480 V



AFE rectifier



Grid-feeding inverter



Grid-forming inverter

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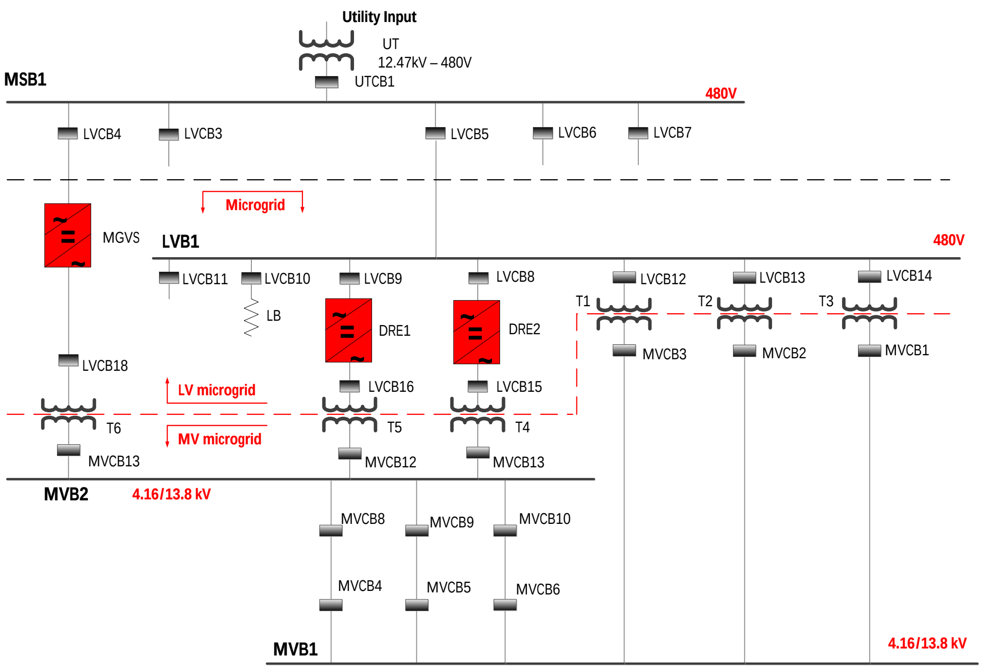
Purposes of the Test Bed

- Research on microgrids
- Test with regenerative power (at low cost)
  - Commercial products for customers
  - Academic prototypes for students
- Develop control algorithms that are robust against cyber attacks



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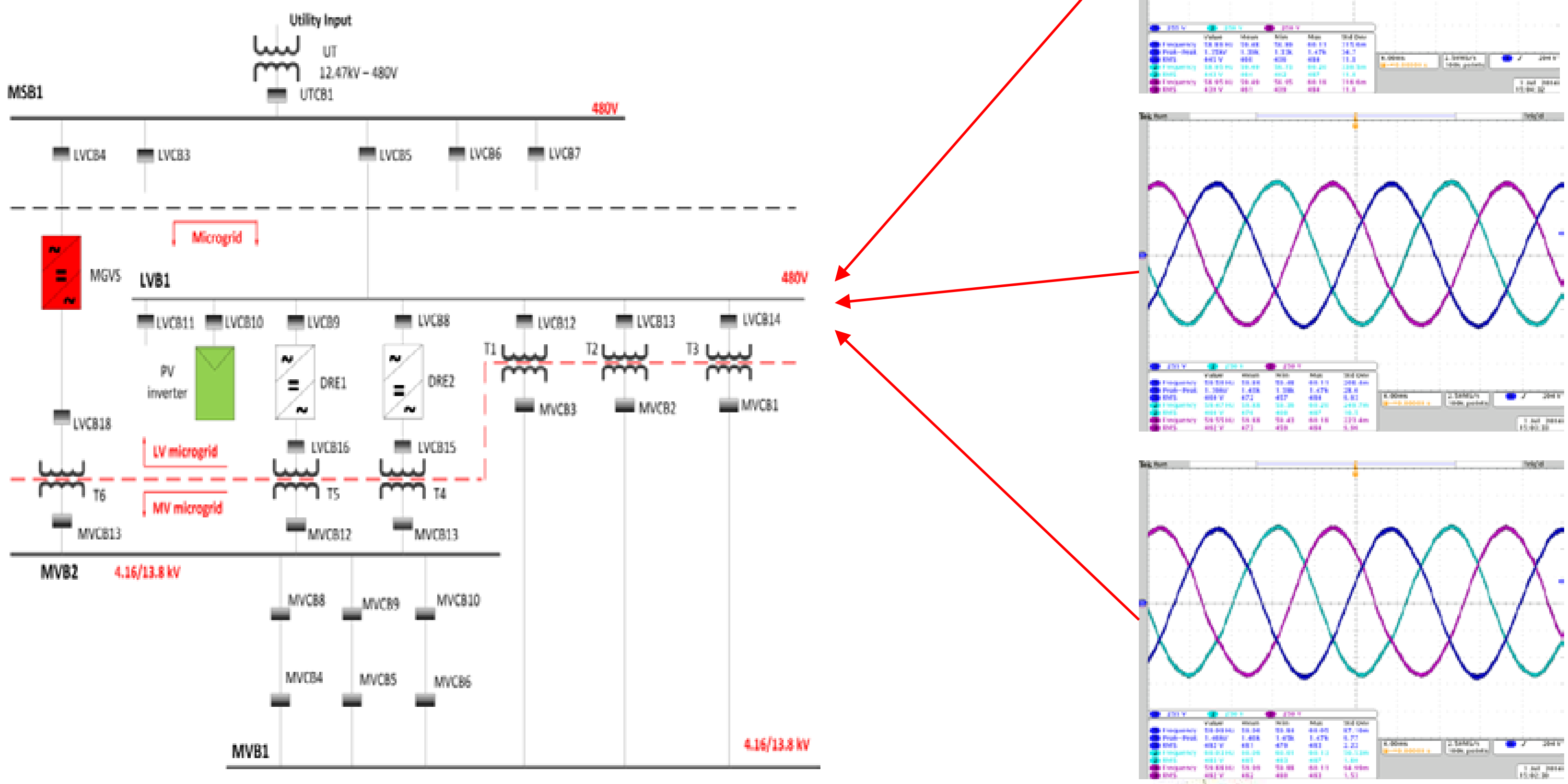
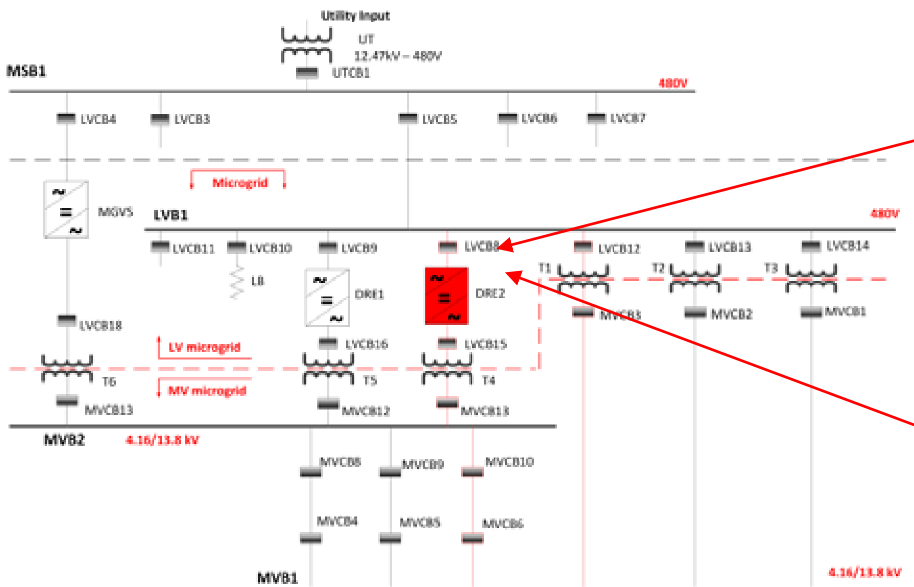
Hardware Experimental Results

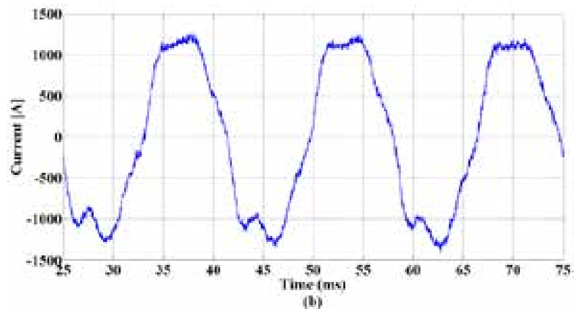
- Test commercial products for customers with regenerative power



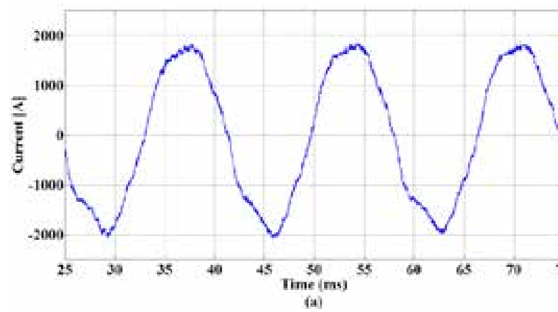
Hardware Experimental Results

- DRE regenerates power in grid-connected mode





30% (0.72 kA rms)



50% (1.2 kA rms)

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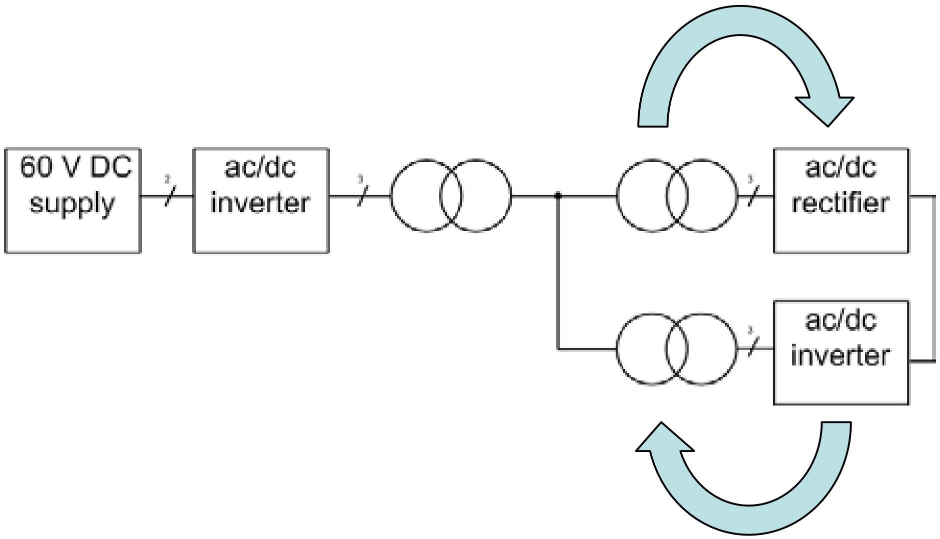
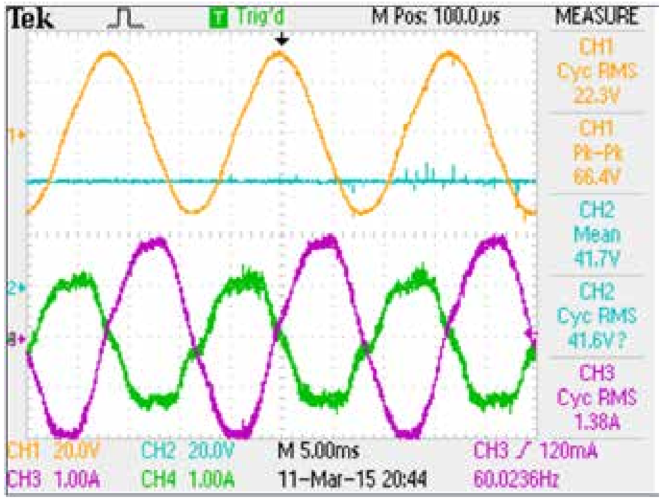
High Power Test Bed Challenges

- **Safety Environment**
  - **Scaled-down prototype for verifying microgrid topologies and control algorithms**
  - **Test engineer**

(a)



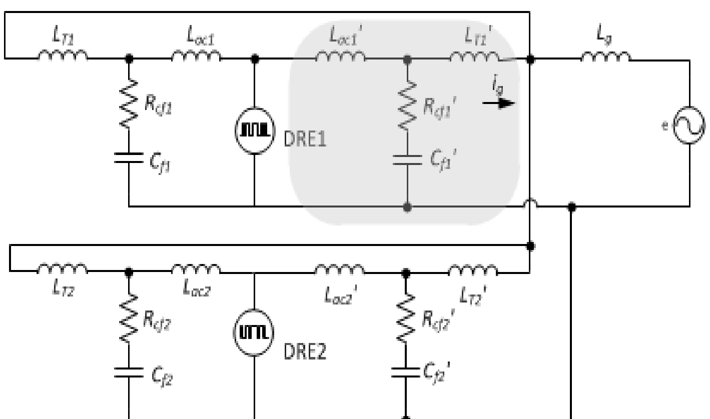


High Power Test Bed Challenges

- Safety Environment
- Power losses
- Microgrid stability (resonant propagation)

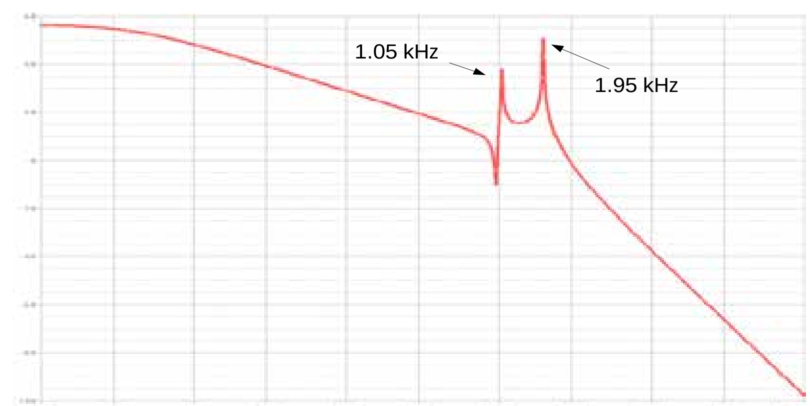
$$f_{res} = \sqrt{\frac{1}{C_f}\left(\frac{1}{L_{ac}} + \frac{1}{L_g}\right)}$$

$$i_g / U_1 = \frac{(C_f R_{cf} \cdot s + 1)}{[C_f L_{ac} L_g \cdot s^3 + C_f R_{cf} (L_{ac} + L_g) \cdot s^2 + (L_{ac} + L_g) \cdot s]}$$



(a)

Filter equivalent circuit



(b)

PSpice[TM] Bode plot

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Conclusions

- A microgrid laboratory test bed was proposed
- The preliminary experimental tests (in both grid-connected and island modes)

Future Work

- Software developments for future microgrid research
  - Droop control
  - Active damping
  - transition-to-island mode and reconnection mode
- Microgrid energy management

ACKNOWLEDGEMENT

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GRAPES

GRid-connected Advanced Power Electronic Systems


감사합니다
Natick
Grazie
Danke
Ευχαριστίες
Dalu
Obrigado
Thank You
Köszönöm
Tack
Спасибо
Dank
Gracias
谢谢
Merci
Seé
ありがとう