

# *The 2005 International Future Energy Challenge*

**Topic B (Utility Interactive Inverter System for Small DG)  
Testing at the National Renewable Energy Laboratory  
Final Competition - August 15-19, 2005**

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# FEC – Test Requirements

- **Utility Interactive Inverter System for Small Distributed Generation:**

The objective of this competition is to improve and foster innovation in the design of flexible utility interactive inverter systems for small distributed generation.

- The inverter must be efficient and comply with requirements for harmonic control, interconnection, and safety standards.
- The inverter must be capable to operate in typical voltage and frequencies, grid-connected or stand-alone.
- The inverter should operate from a dc input voltage varying from 30 volts to 60 volts, under constrained input power varying from 250W to 1000W, to a single-phase utility line 110/240V either 50Hz/60Hz, with efficiency of at least 90%.
- The inverter will be able to work grid-connected (at unity power factor) or stand-alone (providing power for a resistive load).
- The inverter must draw all its internal power from the input side. Hardware prototypes capable to meet the specifications will be tested.



# FEC – Test Requirements

- **Utility Interactive Inverter System for Small Distributed Generation:**

- Output power capability : Must deliver energy into a grid with automatic detection. The ranges that will be tested are 110 V +15% -20%, at 60 Hz  $\pm$  2% and 240 V +15% -20%, at 50 Hz  $\pm$  2%. The unit must disconnect automatically from the utility grid and keep a stand-alone emergency load (maximum 250 W) if an external blackout or abnormal operating conditions occur with the grid interconnection. The unit will also be tested in stand-alone for powering a 1000 kW resistive load. The voltage tolerance should be  $\pm$ 10% for all power range.
- Peak power rating : 3000 W peak for a 1000 W continuous rating.
- Improved overall efficiency curves : Should be included in the final report showing efficiency for power level varying from 5% to 100%.
- Stand-by (tare) losses, i.e., when the inverter is on, but not producing power (low load). - Less than 3% of full rating.
- Harmonic quality : In accordance to IEEE 519 and IEEE 1547.
- Input source : 30 VDC to 60 VDC under programmable power. The input source is unidirectional and not capable to absorb any power back.



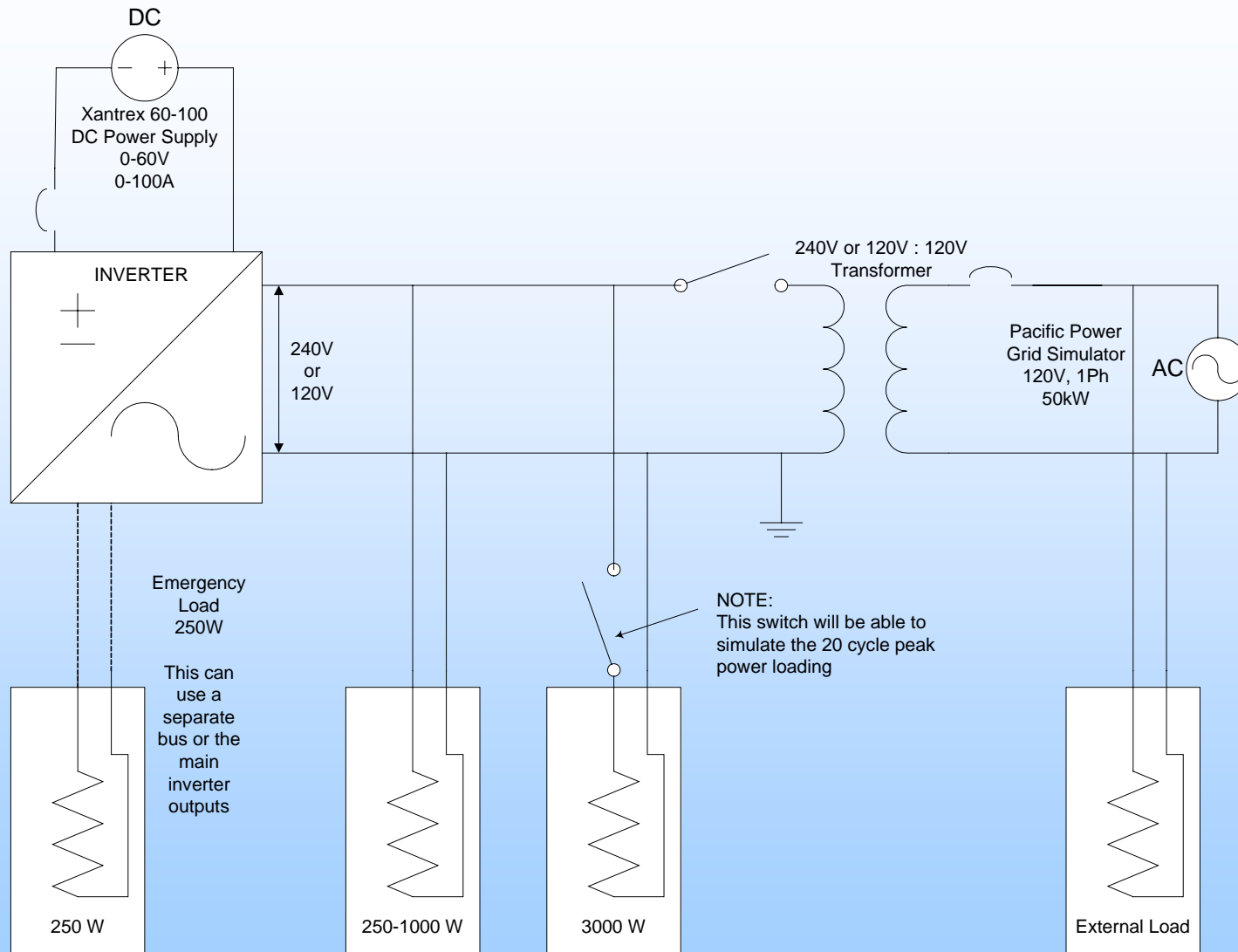
# FEC – Test Requirements

- **Utility Interactive Inverter System for Small Distributed Generation:**

- **Load :** The inverter will be tested in grid-connected mode and will have to be able to provide all the output power range at unity power factor. The inverter has to automatically detect blackout, disconnect from the grid and keep an auxiliary load of up to 250 W operating normally. The inverter will also be tested in stand-alone. In stand-alone, it has to generate either 50 Hz or 60 Hz (maybe configured by jumpers) and capable to power a resistive load of 1000 W.
- **Overall energy efficiency :** Higher than 90% for a 1.0 kW resistive load. Additional scoring points will be awarded for efficiencies higher than 90%.
- **Output Protection :** Over/Under Voltage in grid connected mode. Over current and short circuit in stand-alone mode. No damage caused by output short circuit.



# FEC – Test Configuration





# FEC – Test Procedure

## Utility Interactive Inverter System for Small Distributed Generation:

1. **Inspection** - All prototypes of approved Finalist teams must pass safety inspection prior to operation. The inverter should not have live exposed parts. All prototypes must function correctly during a 5-minute initial operation check before proceeding.
2. **Grid connected Mode Test**
  - a. Measure full output – should be at least 1000W
  - b. Harmonic Measurement – should meet
  - c. Vary input voltage (30,40,50,60) – see next page
  - d. Ramp voltage up (110%) and down (88%) while grid connected (unit should remain running)
  - e. Ramp voltage to (115%) and down to (80%) while grid connected (unit should disconnect from grid)

# FEC – Test Procedure

## 2. b. Harmonic Levels

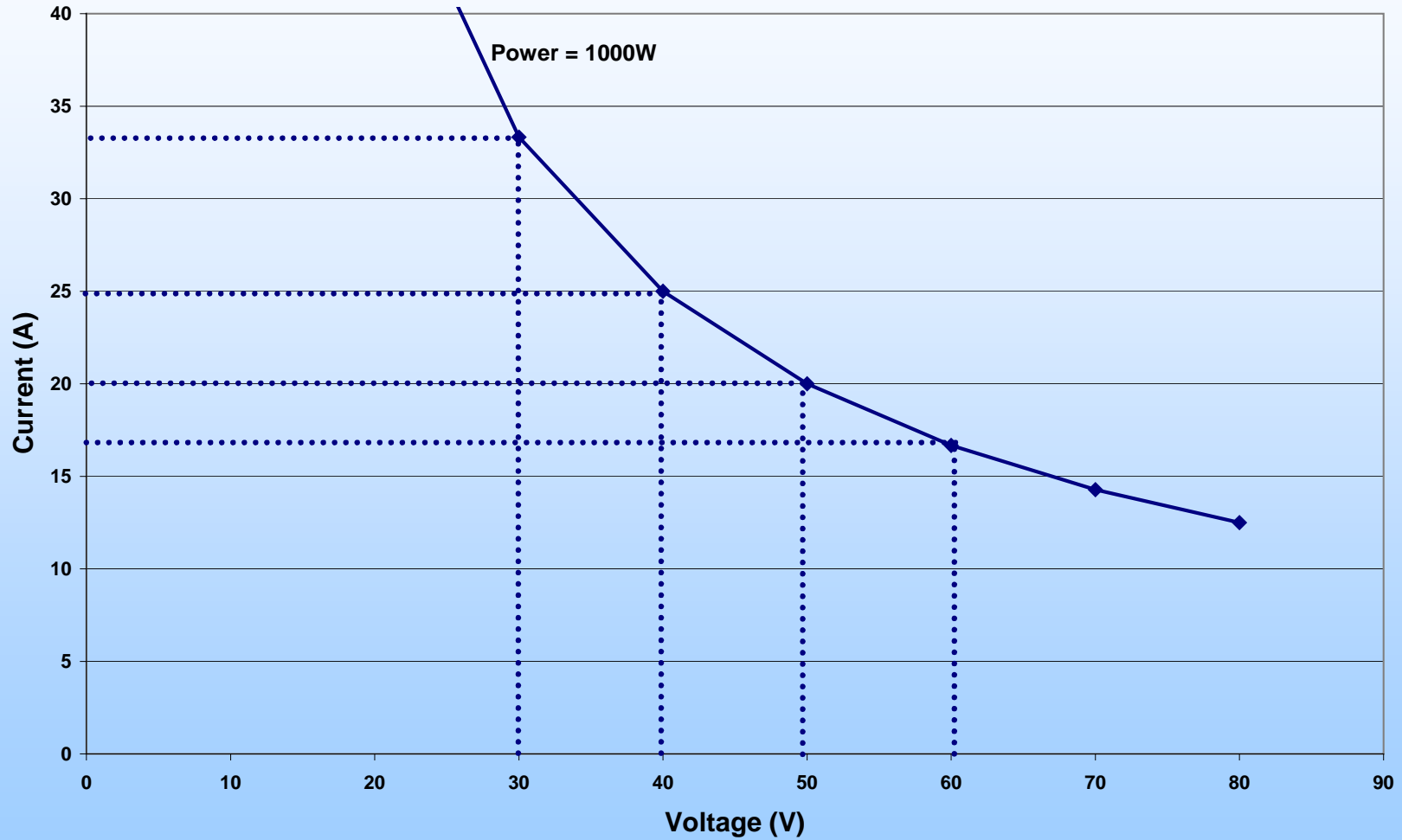
Maximum Harmonic Current Distortion in Percent of Current (I) per IEEE 1547

Individual Harmonic Order (Odd Harmonics)	<11	$11 \leq h < 17$	$17 \leq h < 23$	$23 \leq h < 35$	$35 \leq h$	TDD (THD)
Percent (%)	4.0	2.0	1.5	0.6	0.3	5.0

Notes. Even harmonics are limited to 25% of the odd harmonic limits noted.

# FEC – Test Procedure

## 2. c. Input Voltage Variation (30, 40, 50, 60V)







# FEC – Test Procedure

## Utility Interactive Inverter System for Small Distributed Generation:

### 3. Loss of Grid Test

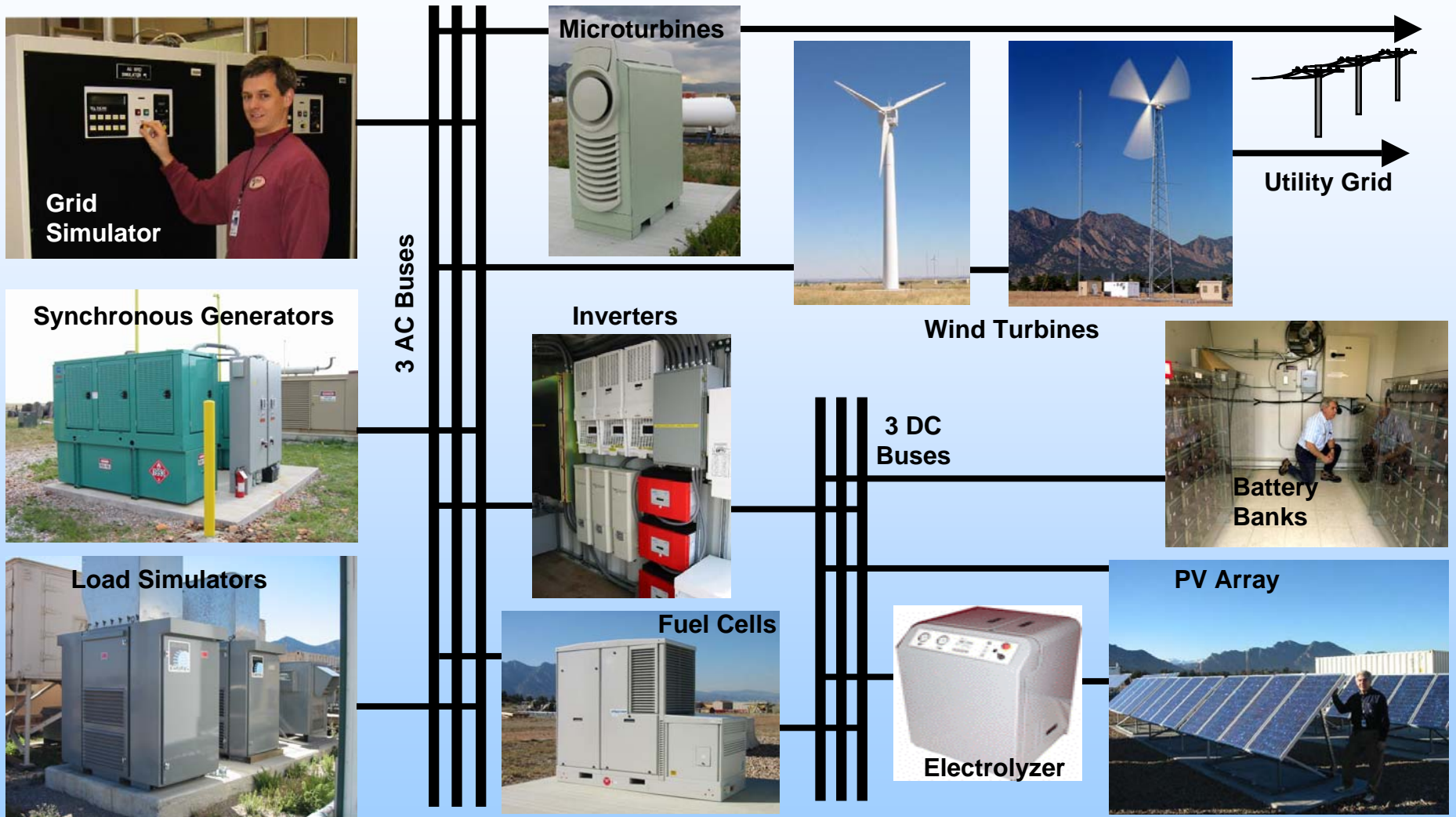
- a. Disconnect grid with switch, Inverter should carry 250W emergency load on separate terminals

### 4. Stand-Alone Test

- a. Measure Stand-by (Tare) Losses – Inverter is on, but not producing output
- b. Efficiency Test - Set output load to (250W, 500W, 750W, 1000W) at both 30V and 60V input level
- c. Measure output in stand-alone mode should be able to supply 1000W continuous and 3000W load for 20 cycles



# NREL's DER Test Facility





# NREL's DER Test Facility



**DC Bus** – Allows up to 10 DC device (Battery, PV) connections

**AC Bus** (3Phase, 480V, 400A rated) – Allows up to 15 AC device (inverters, microturbine, generators) connections

**Switch Panel** – Computer controlled. Allows tester to easily configure systems. Ability to run 3 independent systems simultaneously.





# NREL's DER Test Facility

- **Testing ranges**
  - Voltage: 0-480V ac and 0-600V dc
  - Current: 0-400A ac and 0-400A dc
  - Frequency: 0-400Hz (Grid Simulator)
  - Total Power Testing Nominally 200kW
- **Data Acquisition Systems**
  - National Instruments based DAS built into AC and DC bus work (Measures voltage, current, frequency on 15, 3-phase AC devices and 10 DC devices).
  - New high Speed National Instruments DAS for mutli-DR test container – minimum of 44KS/s on 45 nodes.
  - Two Yokogawa PZ4000 Power Analyzers – up to 5MS/s on a total of 8 16 channels.



# NREL's DER Test Facility

- Installed Distributed Generation
  - 10kW PV Array
  - 10kW, 60kW, 100kW Wind Turbine
  - (2) 40kW, 80kW, 125kW Diesel Generators
  - 30kW Microturbine
- Grid Simulator – 200kW
  - (4) 50kW Pacific Power Source – Variable AC voltage, current, frequency, harmonic level
- Load Banks
  - 40kW resistive – 5kW steps
  - 100kW resistive (5kW step), 175kW Inductive (5kVar step)
  - 165kW resistive (1.25kW steps), 404kVar (Inductive, Capacitive) (312.5kVar steps)
- KeyTek Surge Tester – Surge testing – IEEE C62 and IEEE C37

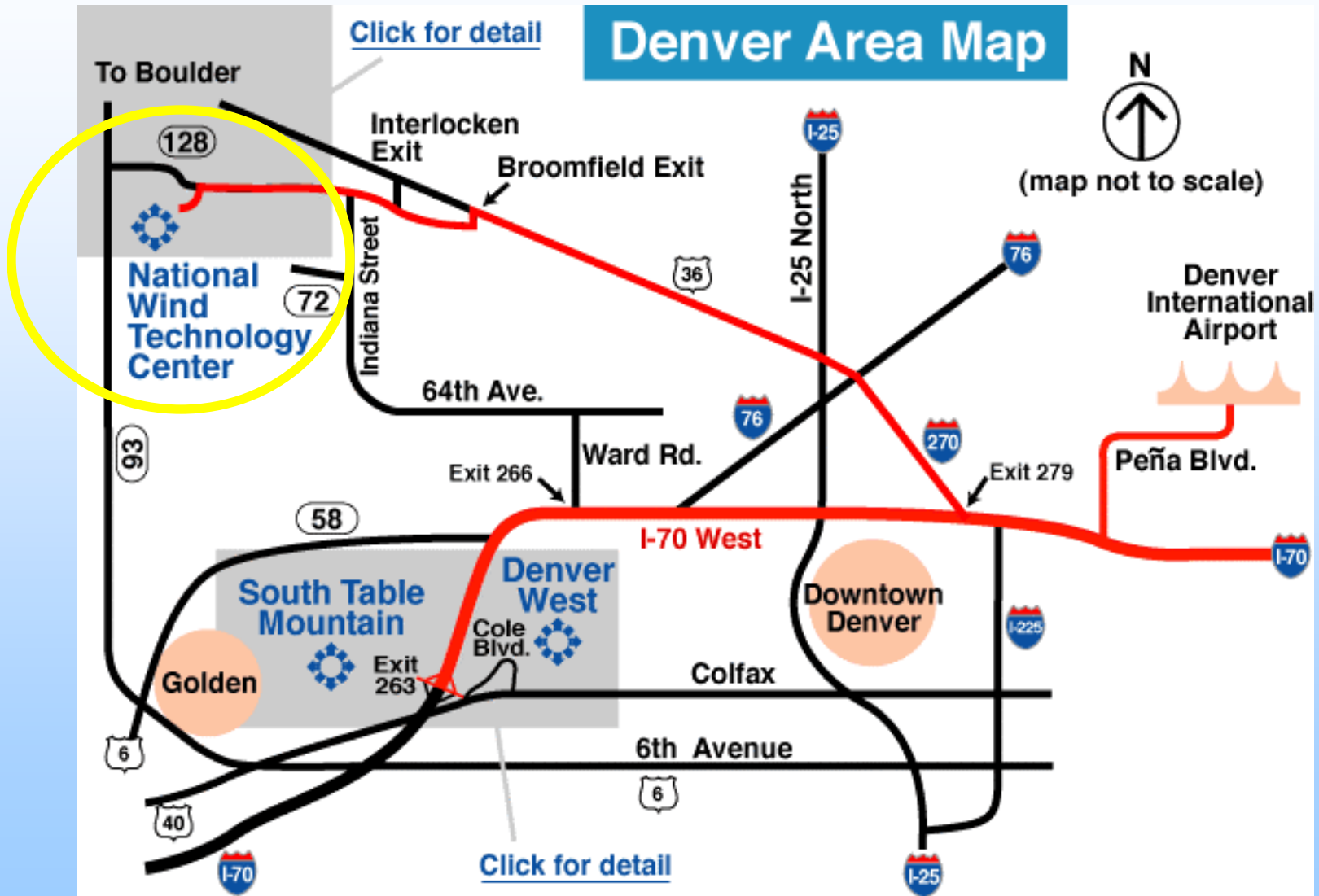


# NREL – National Wind Technology Center



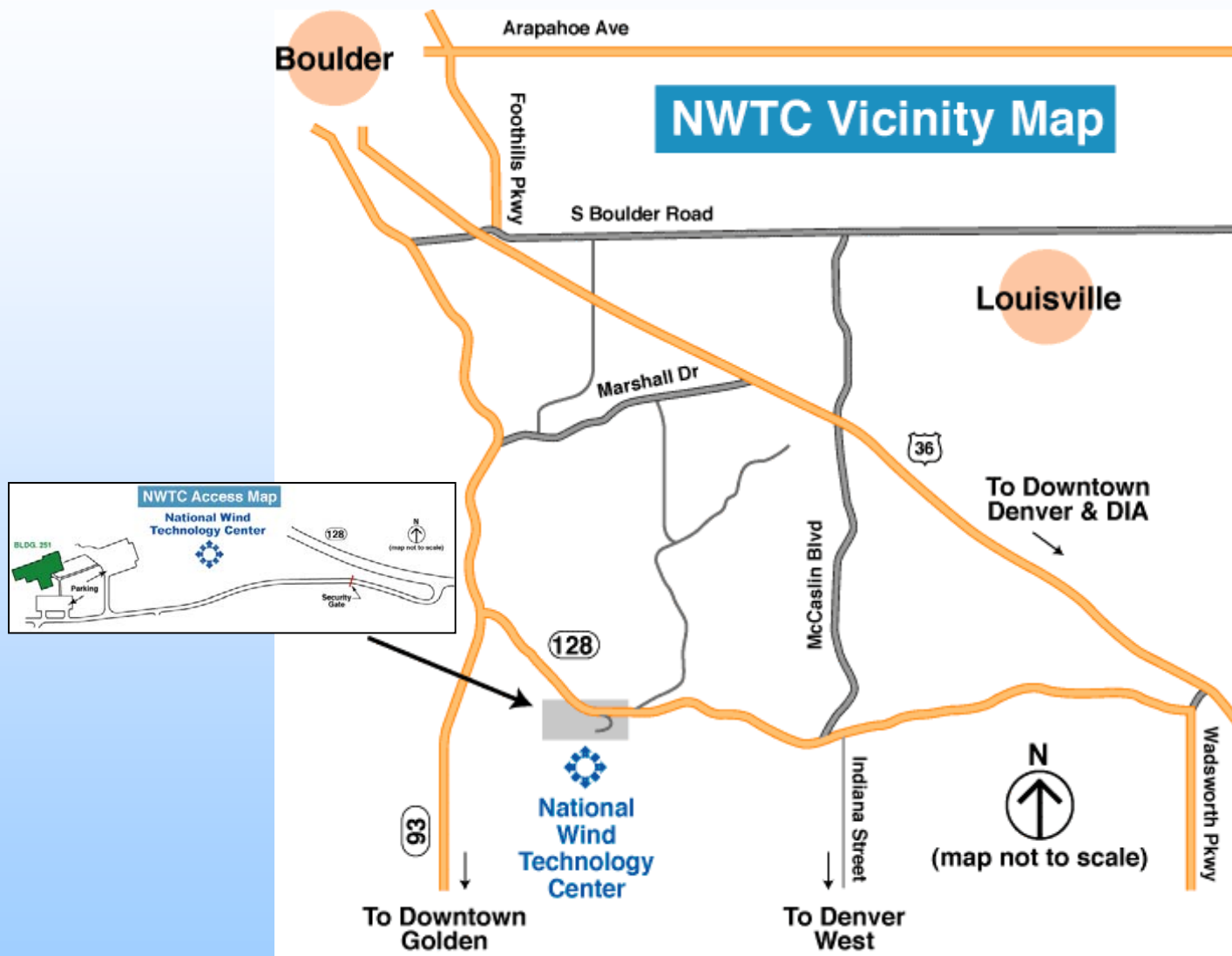


# NREL Visitor Requirements – Site Map





# NREL Visitor Requirements – Site Map



Lodging Options: [http://www.nrel.gov/visiting\\_nrel/nwtc\\_lodging.html](http://www.nrel.gov/visiting_nrel/nwtc_lodging.html)





# NREL Visitor Requirements – Directions

## From Denver International Airport

To reach the NWTC from Denver International Airport (approximately 37 miles), use the airport access road, Peña Blvd., to exit the airport and then merge onto I-70 heading west.

Follow I-70 west for 4.9 miles to Interstate 270 west (Exit 279). Follow I-270 west for approximately 5.5 miles until it ends and merges into Highway 36 west.

Follow Highway 36 west approximately 9 miles and exit at the Broomfield/Lafayette exit. At the top of the exit ramp, turn left at the traffic light.

Proceed through a second light, then bear right at the third light onto State Highway 128 west.

Continue west on State Highway 128 for 7 miles, past Indiana Street, and turn into the entrance of the NWTC on your left.

All visitors must check in with the receptionist (in Building 251) for access approval, a visitor's badge, and **site-specific security procedures**.



# NREL Visitor Requirements

Upon arrival at the NREL gate, you must check-in with NREL Security at the Site Entrance Building and provide government-issued photo identification (e.g., driver's license, passport, military ID).



Security staff will provide you with a visitor's badge and direct you to Building 251 to meet your host.

Visitor vehicles are **not** permitted in any other areas except the designated visitor's parking area outside Building 251.

Foreign Nationals should check with their host prior to their visit to make sure that a **Foreign National Data Card** has been signed and approved.



# NREL Foreign Visitor Requirements

## NREL FOREIGN NATIONAL DATA CARD

### PERSONAL INFORMATION:

1. Name of Visitor or Assignee:		
<i>Please Print:</i> (Last)	(First)	(Middle)
2. Country(s) of Citizenship:	3. Date of Birth (mm/dd/yyyy):	4. Place of Birth:
(List All)		(City or Region) (Country)
5. Gender: <input type="checkbox"/> Male <input type="checkbox"/> Female		6. Permanent Resident Alien: <input type="checkbox"/> Yes <input type="checkbox"/> No

### VISITOR/ASSIGNEE'S EMPLOYER INFORMATION:

7. Employer, Institution, or Organization represented:	9. Employer/Institution/Organization Country:
8. Title or Expertise (not required):	10. Employer/Institution/Organization Address:

### VISA INFORMATION: INFORMATION:

### PASSPORT

11. Visa Type:		15. Passport Number:
<input type="checkbox"/> J-1 <input type="checkbox"/> Other: _____		_____
12. Visa Number:	13. Expiration Date (mm/dd/yyyy):	16. Issuing Country:
14. Visa Status Remarks:		17. Expiration Date (mm/dd/yyyy):