



# MN-PUC - SMART Grid Renewables on the Distribution System

Martin Morud  
Owner/President

Steve Peichel  
Electrical Engineer

# Past Topics

- **January 6, 2012: SMART Grid and Data Privacy**
- **April 20, 2012: Reliability and Operations**
- **April 5, 2013: Time-of-Use Rates**
- **September 27, 2013: Microgrids**

**CSGs      VOST      SR      CO2      ELCC**  
**Aurora      RDF      Studies**

- **April 11, 2014: Renewables on the Distribution System**

# Renewable Energy World Headlines

04-01-2014

[Solar Decathlon Houses Make Up a Solar Village to Test Microgrid Technology](#)

[Building the Electricity System of the Future: Thinking Disruption, Doing Solutions](#)

[Solar Energy Set to Provide Power for Australia's Mining Industry](#)

[Borrego, San Diego Airport Partner on 3.3-MW Solar Project](#)

[Panasonic Hesitant to Commit to Tesla Battery Factory](#)

[Are Walmart's Green Claims Simply Greenwashing?](#)



UNIVERSITY OF MINNESOTA



POLYMET  
MINING

Minneapolis • Saint Paul  
INTERNATIONAL AIRPORT

mSP

going your way



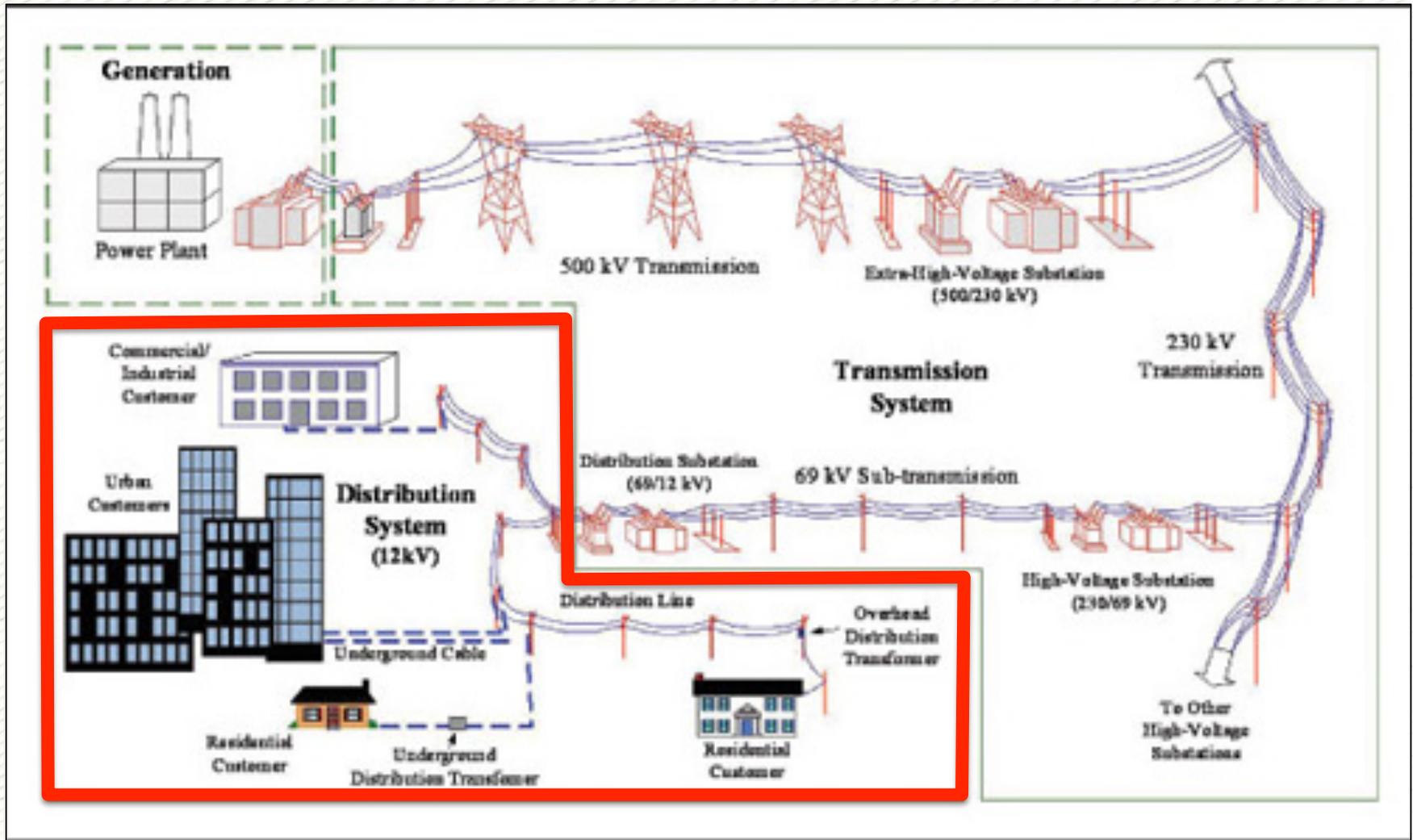
Medtronic

Walmart 

# Renewables on the Distribution System

- 1. Interconnection Process**
- 2. Real-life situations solar installers encounter**
- 3. Advanced Inverters**
- 4. Policy Opportunities**

# Renewables on the Distribution System





# What does a Real Interconnection Look Like?

**\$250**



Please complete the Application and the required supporting information, along with the \$250 Application Fee payable to “Xcel Energy”, and return to:

Xcel Energy will review your Application and provide comments back to you within 15 business days regarding the feasibility, technical review fee, and technical review time requirements of your Interconnection request.

**Time**



**Engineering**



Please note that compliance with IEEE 1547 is required for all distributed generation systems. Inverter based systems shall meet the requirements of UL1741. UL 1741 certified inverters up to 500 kW are considered satisfactory to meet the protective relaying equipment interconnection requirements of Xcel Energy, with certain exceptions. Requests for non-UL 1741 certified inverters are subject to a complete technical review and testing process, resulting in additional expenses to meet Xcel Energy requirements.

**UNIFORM STATEWIDE CONTRACT FOR COGENERATION  
AND SMALL POWER PRODUCTION FACILITIES (2005)**

- A **One-Line** diagram, or circuit diagram, showing the installation of your system is required. The following information is required on the 1-line:
  - Customer name, installation address, and installer name and contact info.
  - Main service meter and main service panel
  - Production meter, if applicable. Note ownership.
  - Visible, lockable AC disconnect for Utility use.
  - All Switches, Breakers, fuses, Junction boxes, Combiner boxes, protective devices, etc. in the electrical circuit from the main service meter to the generation system.
  - Generator system (PV Panels, wind turbine, etc)
  - Clearly provide electrical ratings of the above equipment. Volts, Amps, # phases, kW, etc.
  - Clearly note if the Inverter(s) are UL1741 certified.
  - Indicate both new and existing generation systems.
- **Site Plan** or location plan identifying location of equipment noted on the 1-line.
  - Customer name, installation address, and installer name and contact info.
  - Building and Streets identified and Nautical direction
  - A detail view or plan view may be required to clearly show location of meters, main service and AC disconnect, i.e. interior or exterior wall, etc.
  - Note distance between equipment. The AC Disconnect should be readily accessible and located within 10' of the main service meter.
  - Include location of new and existing systems.
- **Label Details**
  - Labels to be weatherproof, durable and permanently mounted.
  - Demonstrate compliance with NEC
  - Include label on Main Service Meter, "Generation System Connected", or similar.
  - Include Label "Utility AC Disconnect"
- **Test procedure** that will be used to verify the protection and operation of the system shall be submitted to Xcel Energy for approval. The system cannot backfeed the Xcel Energy system upon loss of the Utility source.
- **Proof of Insurance** per the Interconnection Agreement.
- After the Application and all supporting information is received and approved, Xcel Energy will provide information to schedule an appointment for the meter installation and final testing.
- A signed copy of the test report verifying the test procedure was successful shall be provided to Xcel Energy.



# Description Online

4/0 AWG Cu, 124.8 Amps per phase, 4-wire, approx. 220 feet to AC disconnect

2/0 AWG Cu, 124.8 Amps per phase, 4-wire, approx. 10 feet to Production Meter

6 AWG Cu, 75 deg C, 41.6 Amps per phase, 3-wire, approx. 100 feet to collection panel

8 AWG Cu, 75 deg C, 24 Amps per phase, 3-wire, approx. 50 feet to collection panel

2 AWG Cu, 75 deg C, 102 Amps, 2-wire, approx. 5 feet to inverter

PV DC Fused Combiner Box  
Midnite Solar MNPVLV

80 amp circuit breakers

12 Panels per branch, 24 Panels total  
2 AWG Al, USE-2 (90 deg C), 62.4 Amps, 2-wire, approx. 5 feet to inverter

12 Panels per branch, 24 Panels total  
2 AWG Al, USE-2 (90 deg C), 57.2 Amps, 2-wire, approx. 5 feet to inverter

11 Panels per branch, 22 panels total

## INVERTER NOTES

### INPUT DATA

- Sustainable Energy Technologies, ELV-208 5000Watts
- CEC Efficiency = 94.0%
- Max DC volt rating = 57 Volts
- Max DC Input Current = 102 Amps

### OUTPUT DATA

- Max Continuous Output Power = 5000 Watts
- Nominal AC Voltage = 208 Volts, Single-Phase
- Nominal Frequency = 60 Hertz
- Max AC continuous output current per inverter = 24 Amps
- Max Output Overcurrent Protection = 30 Amps
- Power Factor: <2% THD, IEEE 519 Compliant

### OUTPUT DATA

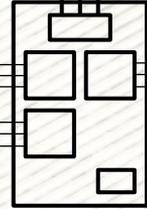
- Internal Ground Fault Detect Interrupt (GFDI) and anti-islanding protection in accordance with UL 1741
- Operating ranges and trip times adjustable according to local regulatory limits

## MODULE NOTES

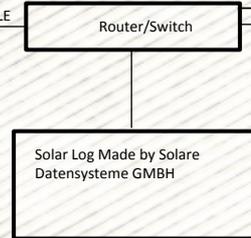
- TenkSolar RAIS PV Module 190W-M (90 Monocrystalline silicon Half-cells)
- Vmax = 57 Volts, this is a regulated output voltage
- Imax = 5.2 Amps
- Vnom = 52.5 Volts
- Voc = Isc = 0 (unique power electronics control feature to tenksolar's product)
- Integrated Ground Fault Detect Interrupt (Compatible with Inverter GFDI), internal ground fault limit is 500 mA

## ARRAY

- 24 panels per inverter
  - Two branches per inverter, 12-panels per branch
- 22 panels per inverter
  - Two branches per inverter, 11-panels per branch
- All panels are in parallel and two branches are paralleled at combiner box
- Array mounted on flat roof
- See next page for phase layout



3-phase Collection Panel (Outside)  
208 Volt AC,  
200 Amp Panel  
200 Amp Main Breaker  
3-60 Amp Breakers

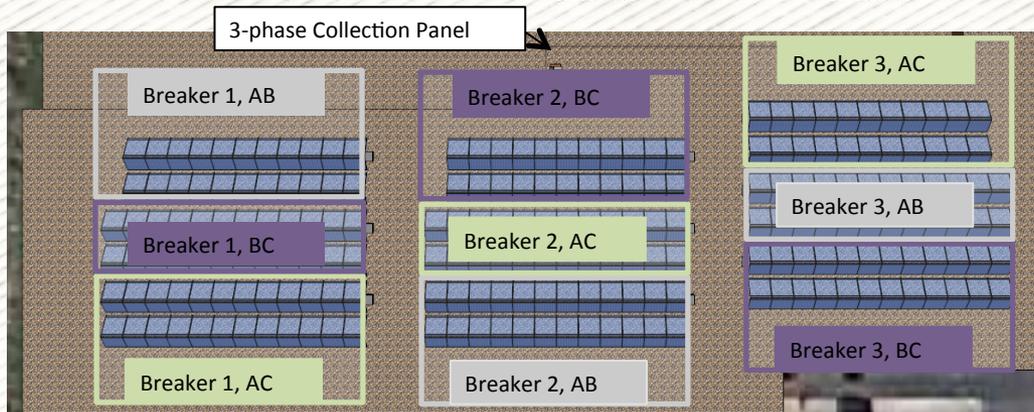
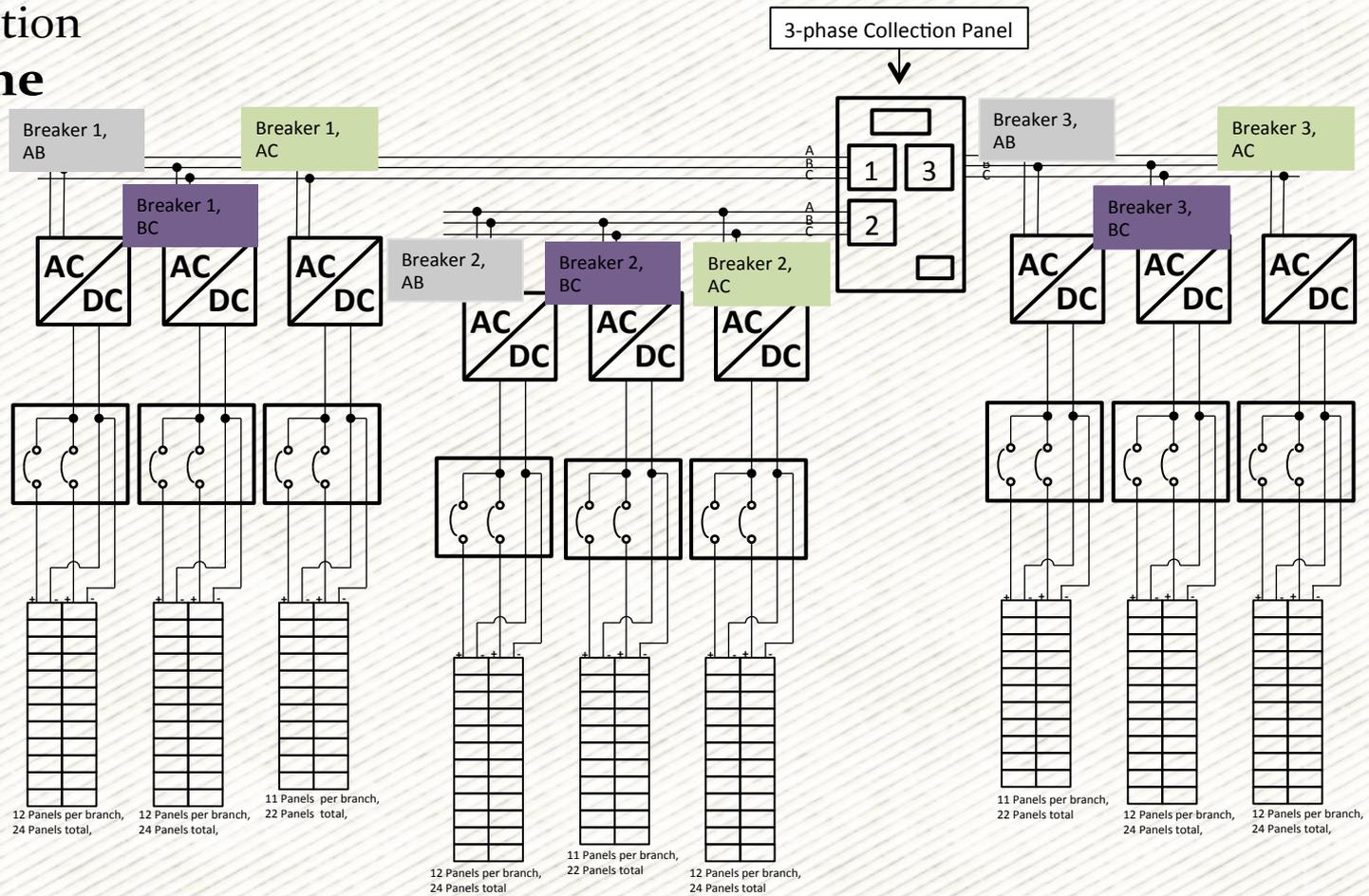


## SYSTEM NOTES

- 210 total panels
- Rated Power = 39,900 Watt DC; 40,000 Watts AC (Total AC Inverter Rating)
- Inverter per 3 branches, converts DC to AC
- Nominal AC Voltage = 208 VAC
- Max AC Current = 124.8 Amps
- Designed per NEC Standards

REV	DATE	DRAWN	DESCRIPTION	WORK ORDER	CHKD	APPD	DATE
A	02/14/13	M	PRELIMINARY ISSUE				
<b>CEG CONSULTING ENGINEERS GROUP</b> FARMINGTON MINNESOTA							
<b>ONE LINE DIAGRAM</b> <b>40KW BRIDGING SOLAR</b>							
I HEREBY CERTIFY THAT THIS PLAN, SPECIFICATION, OR REPORT WAS PREPARED BY ME OR UNDER MY DIRECT SUPERVISION AND THAT I AM A DULY LICENSED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF MINNESOTA				CHECKED _____ DATE _____		SCALE NONE	
NAME _____ DATE _____		REGISTER NO. _____		W.O. NO. CEGLR001		DWG. NO. _____	
DRAWN _____ DATE 02/18/2013				03BR-0101			

# Description Online



REV	DATE	DRAWN	DESCRIPTION	WORK ORDER	CHKD	APPD	DATE
A	02/14/13	MAM	PRELIMINARY ISSUE				
			<b>CONSULTING ENGINEERS GROUP</b> FARMINGTON MINNESOTA				
I HEREBY CERTIFY THAT THIS PLAN, SPECIFICATION, OR REPORT WAS PREPARED BY ME OR UNDER MY DIRECT SUPERVISION AND THAT I AM A DULY LICENSED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF MINNESOTA.							
NAME _____ DATE _____ REGISTER NO. _____				CHECKED _____ DATE _____		SCALE NONE W.O. NO. CEGLR001	
				DRAWN MAM DATE 02/18/2013		DWG. NO. <b>03BR-0102</b>	

# Description Equipment Labels

Label #1	Code Ref.	Location	Wording
1	690.14 (C) 2	Near the PV system AC disconnect.	Photovoltaic System AC Disconnect
2	690.53/690.54	Near the PV system AC disconnect.	Photovoltaic System Spec's AC Rated Power = 45,000 Watts Max AC Current = 124.8 Amps Nominal AC = 208 VAC
3	690.17	Near the PV system AC disconnect.	Warning - Electric Shock Hazard. Do not touch terminals. Terminals on both the line and load side may be energized in the open position.
4	690.56 (B)	Near the PV system AC disconnect.	The service disconnect for this building is located here (arrow).
5	-	On Main Service Panel	THIS SERVICE PANEL IS ENERGIZED FROM MORE THAN ONE SOURCE. ONLY AUTHORIZED PERSONS WHO ARE FAMILIAR WITH THIS SYSTEM SHOULD ATTEMPT TO DO SERVICE WORK ON IT.
6	690.56 (B)	At the main service panel	The photovoltaic system disconnect for this building is located here (arrow).
7	230.70 (B)	At the main service panel main disconnect.	Service Disconnect
8	-	Near the main service panel PV system circuit breaker	BACKFED FROM PV SYSTEM INVERTER
9	-	Near terminals of fused disconnect switch, ac disconnect, and main service panel.	PV (+) PV (-)
10	-	Near the utility PV system disconnect.	UTILITY PV SYSTEM DISCONNECT
11	-	SW exterior corner of home on the meter socket of the production meter.	PRODUCTION METER
12		<b>At the Main Service Meter</b>	<b>PHOTOVOLTAIC SYSTEM CONNECTED</b>

Install note: All labels will be made from durable, unalterable hard plastics and be sized for plain viewing at eye level. Text font will be equal to or larger than 48-point font.



5301 Edina Industrial Blvd. #2  
Edina, MN 55439  
Tel: 651-587-6341

Residential Building Contractor  
#BC639643

**Xcel Energy Customer:**

**Acct:** 51-xxxxxx-3  
**Premise #:** 303xxxxxxx  
**Meter #:** KZW00xxxxxxx

**Drawing Details**

**DRAWN BY**  
Stephen M. Peichel

**ISSUE**  
02.18.2013

**E2.0**

# Description

## Testing Procedure

PV System Commissioning Checklist

Building Owner: \_\_\_\_\_

Building Address: \_\_\_\_\_

The following first-time energization procedure is to be conducted safely and put no individuals at risk for injury. If an unsafe act or condition is identified, the procedure is stop and the situation is to be remedied by the experienced authority.

1. Verify all labels are installed on E3.0 in the proper location.
2. Verify that all breakers and disconnects are in the open position.
3. Verify electric utility voltage is within acceptable range (for 208VAC)
4. Close the following switches:
  - A. Install Production Meter
  - B. Close DC Breakers
  - C. Close AC Disconnects and/or Breakers
  - D. Close the backfed PV system AC circuit breaker on the Main Service Panel
5. After waiting 15 minutes, verify no faults occur and that all systems exhibit normal operation.

### ANTI-ISLANDING

6. Open the Exterior AC Disconnect to simulate a utility power outage.
7. Verify inverter's LCD codes and alarms are appropriate for the loss of utility, and verify the voltage on the inverter (load) side before the External AC disconnect has dropped to zero.
8. Close the Exterior AC Disconnect and verify system appears to be in normal operation after 5 minute delay.
9. Verify load side of Main Service Circuit Breaker voltages are within 5% of specified operation and currents in all applicable systems meet expectations in present weather conditions.

I certify that I have conducted the commissioning checklist described above.

Sign/Print name and title:

Installer Representative: \_\_\_\_\_ Date \_\_\_\_\_



5301 Edina Industrial Blvd. #2  
Edina, MN 55439  
Tel: 651-587-6341

Residential Building Contractor  
#BC639643

**Xcel Energy Customer:**

Acct: 51-xxxxxx-3  
Premise #: 303xxxxxx  
Meter #:KZW00xxxxxxx

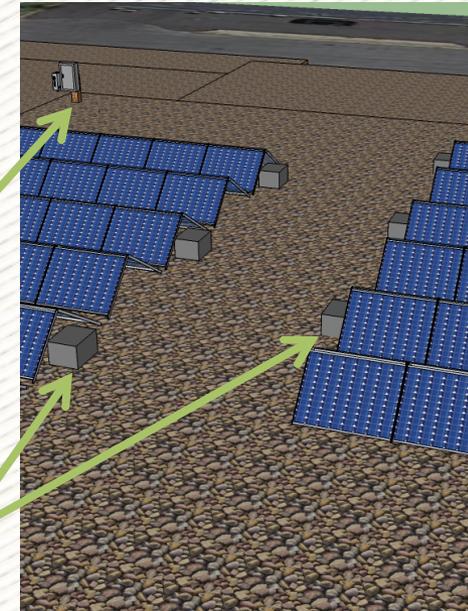
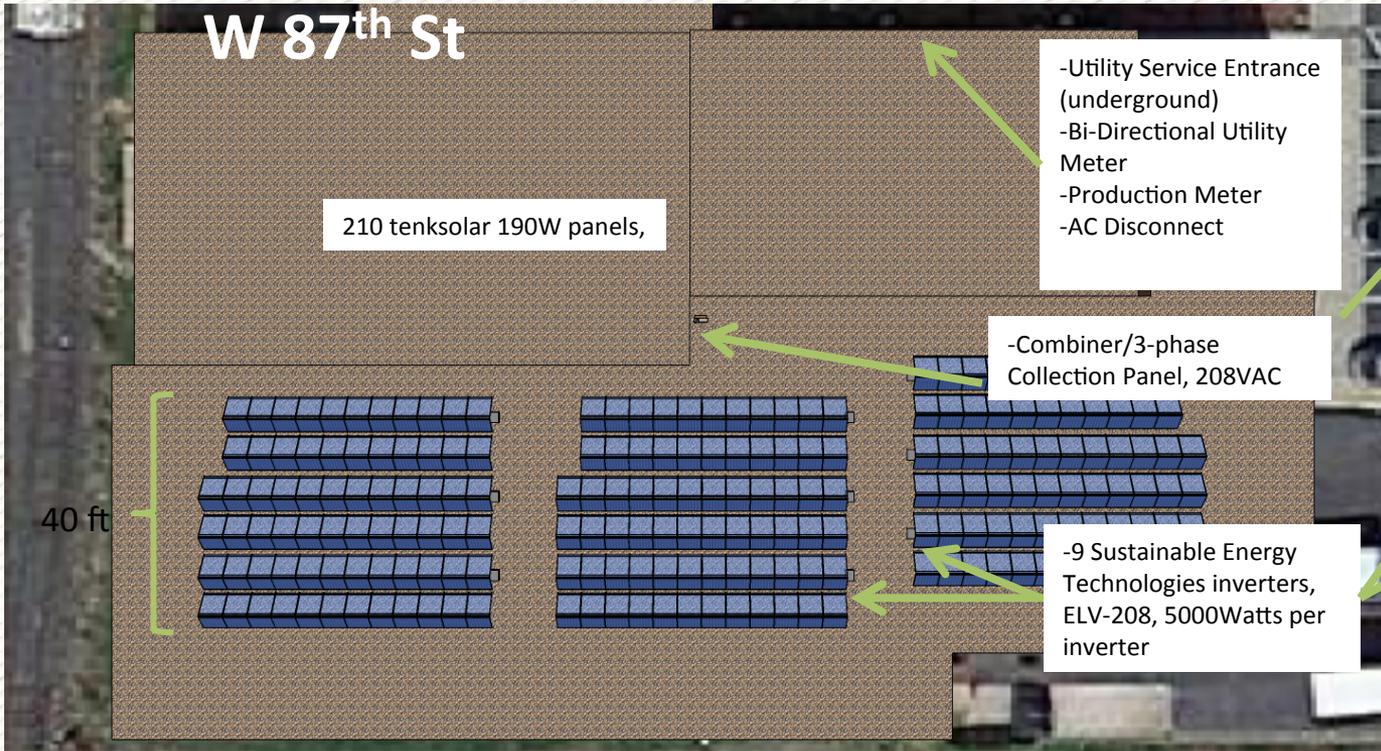
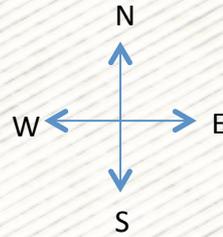
### Drawing Details

**DRAWN BY**  
Stephen M. Peichel

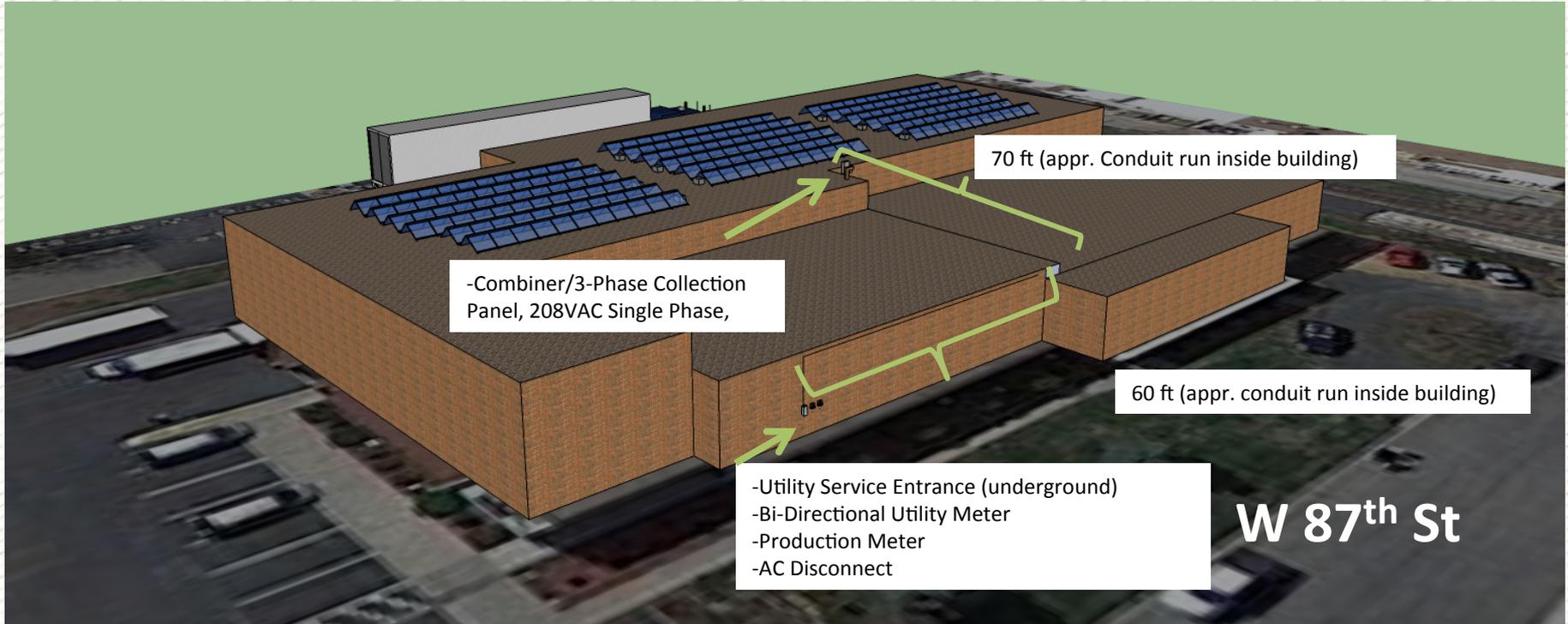
**ISSUE**  
02.18.2013

# C1.0

# Description Site Plan



# Description Site Plan



-Combiner/3-Phase Collection Panel, 208VAC Single Phase,

70 ft (appr. Conduit run inside building)

60 ft (appr. conduit run inside building)

- Utility Service Entrance (underground)
- Bi-Directional Utility Meter
- Production Meter
- AC Disconnect

**W 87th St**

# ***Once Upon A Time***, there was an INTERCONNECTION that...

- 2002 – First Grid-Interconnection Solar installation in Xcel Territory – What Form?
- East Central Energy, Dakota Electric and Connexus have the best turn around time in the state! 24 Hours!!!!
- Transformer upgrades for every interconnect, in every neighborhood?
  - What determines the need for a new transformer?
- “Change Requests” for redundant issues.
- Compliance with IEEE 1547 is required for all distributed generation systems.
- UL 1741 certified inverters up to 500 kW are considered satisfactory to meet the protective relaying equipment interconnection requirements of Xcel Energy.
- Ideally we would follow Germany's example. Install the system, have it inspected and passed by building and electrical AHJs and turn it on. Then go online and register the system with the utility.

# Advanced Inverter Benefits

- Advanced Inverter:
  - Reactive Power (VARs)
    - A flexible source and sink for reactive power
  - Voltage and Frequency Ride-Through
    - Enables a solar power plant to appropriately respond to waveform shape per location, per utility
    - Automated and programmable
    - It's *'SMART'*

# How to implement Advanced Inverters in Minnesota?

- Opportunity with CSG and RDF Development
  - VAR control is more efficient in proximity to substations
  - Distributive benefit by nature
- Run the Calculation:
  - What is the financial benefit of improved local power quality and distribution efficiency?
  - Appropriate VAR support will
    - Resolves phase differences
    - Reduces distribution losses
    - Raises voltage levels
- Or look at your latest commercial bill...

# Common Policy Triggers that result in SMART Grid infrastructure construction.

## **Leadership, Financing and Time**

Perfect Policy:

- Encourages Financing
  - Private reimbursement models
  - Federal partnerships
- Calms uncertainty.
- Does not underestimate reliability.



THANK YOU!

Martin Morud  
Owner/President

Steve Peichel  
Electrical Engineer

# Voltage Control – Requirements

For example...

A utility may have a requirement that voltage drop is less than 2.5%, when generation of the plant changes by 70%.

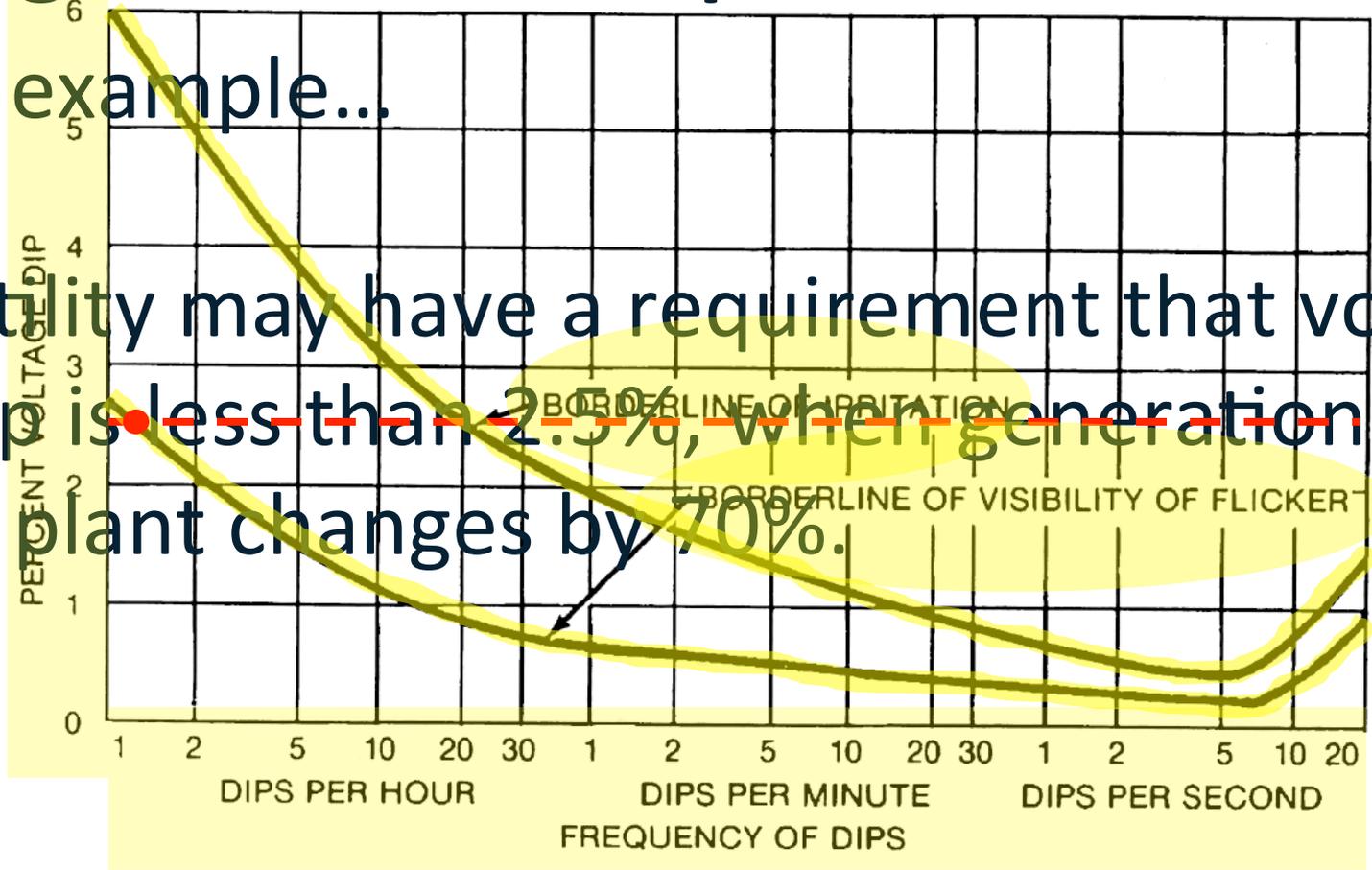
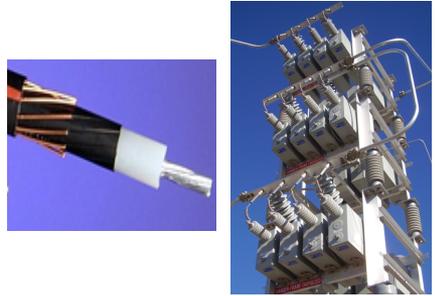


Figure A.1—Flicker tolerance curve from IEEE Std 141-1993/IEEE Std 519-1992

# VAR Flow from the Solar Plant

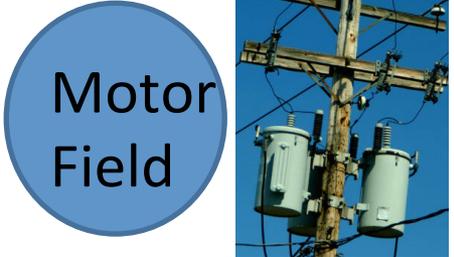
Capacitive



- Cable
- Cap bank

+ var flow,  
supplies vars,  
voltage increase

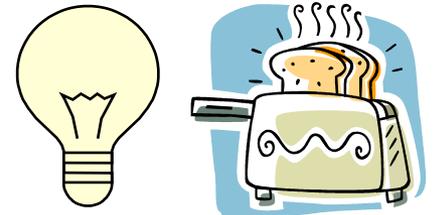
Inductive



- Inductive Power sustains magnetic field
- Motors, transformers

- var flow,  
absorbs vars,  
voltage decrease

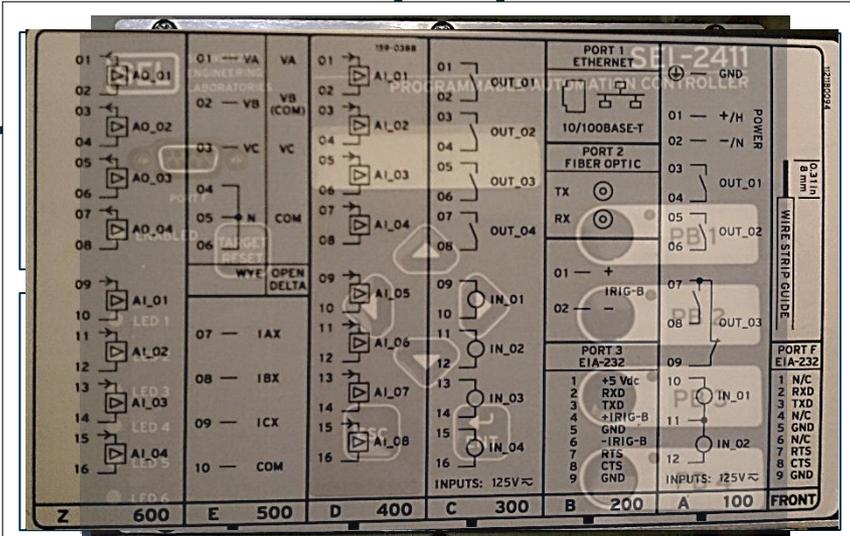
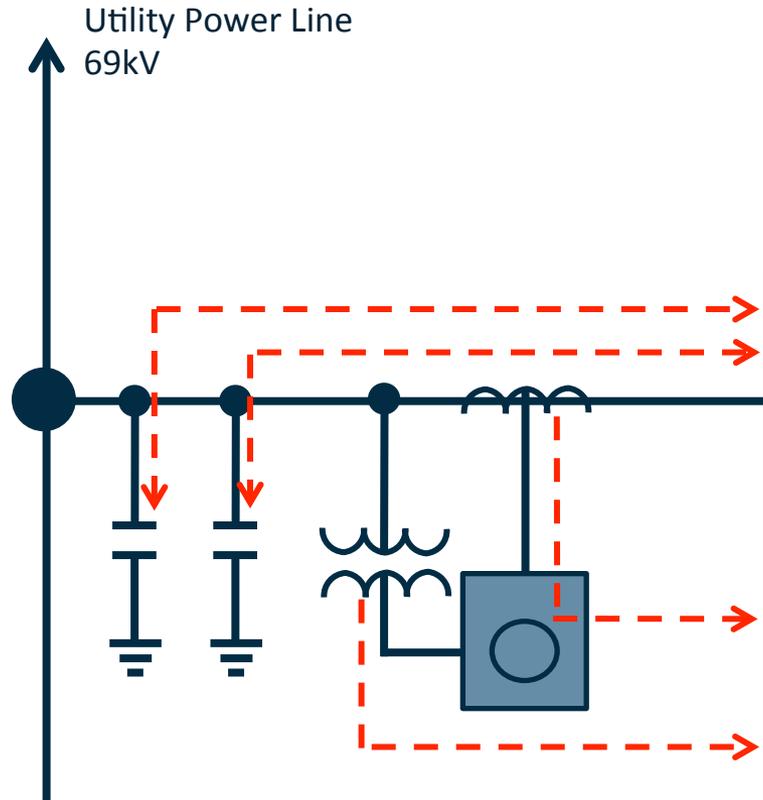
Resistive



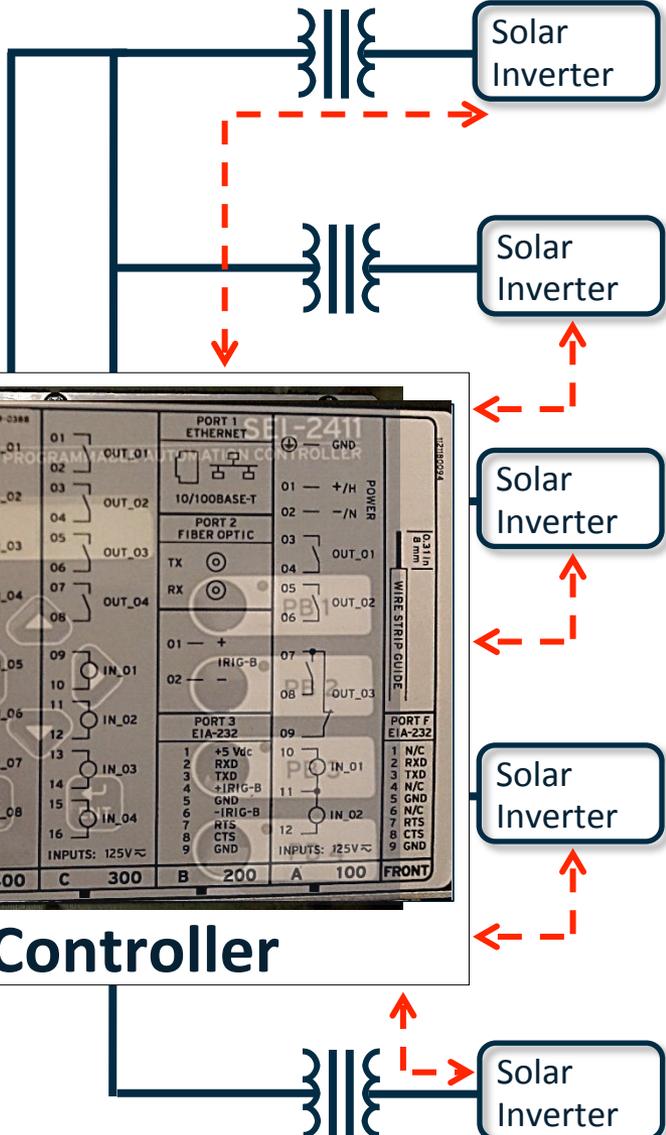
- Light, heat, motion

0 var flow

## Inputs/Outputs



**VAR Controller**





CONSULTING ENGINEERS GROUP



Engineering Powerful Solutions Since 1996

## Variability in Grid System Strength

Weak Utility System = High Impedance

- A system with higher impedance is termed 'weaker' than one with low impedance.
- Less current the system can supply
- Lower Fault Current **1,500 Amps**

Moderate

- Lower Fault Current **10,000 Amps**

Strong Utility System = Low Impedance

- A system with lower impedance is termed 'stronger' than one with high impedance
- More current the system can supply
- Higher Fault Current **20,000 Amps**



CONSULTING ENGINEERS GROUP



## Variability in Grid System Strength

