Solar Grid tied Micro grids System

Strings inverters

µ inverters

µ parallel inverters

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Presentation Overview

- Solar Inverter options
- Types of systems based on inverter choice
- Types of Solar powered Micro Grids
  - Relevant electric codes
  - Systems Architectures using Micro parallel inverters
    - Off grid systems
    - Grid tied systems
    - 3 Phase Grid tied systems
    - Grid tied / Emergency power systems
    - 3 phase Grid tied / Emergency power systems
- Micro-Parallel inverters, designed reduce the cost of generation and maintenance
  - Cost taxonomy based on components installation and maintenance
  - Micro parallel inverter overview.
- Methods of calculating the investment breakeven are presented
  - Curves allow for the quick determination of cost based on;
    - power generation costs (investment),
    - energy value (electric rates),
    - labor rates and component costs are provided.
- An, example of how to determine the investment payback for various configurations

Three classes of Inverters

1. ***String inverter -*** Converts DC to AC for a string of panels

   - High voltage DC inputs
   - Largest in class
   - Conveniently placed near the service box
   - PV panels are connected in series. Voltage builds with each panel
   - MPPT tracking for the string
   - Smart Data limited to an average across the string

2. ***Micro Inverter -*** Converts DC to AC for each panel

   - ***Low Voltage DC voltage inputs < 50V***
   - Size of a small cigar box
   - Mounted on the Panel or just below it on the frame
   - ***MPPT tracking of the inverter for each panel***
   - ***Smart data to the individual inverter and panel***
   - ***Power generation continues with the loss of any given panel***

3. ***Micro- Parallel inverter -*** Converts DC to AC for up to 4 panel with each panel handled as an individual

   - ***Low Voltage DC voltage inputs < 50V***
   - Medium sized (Width of a panel, (designed for single handed blind tool less installation and removal))
   - Conveniently located as desired (Panel, frame, or near service box)

   - ***MPPT tracking of the inverter for each panel***
   - ***Smart data to the individual inverter and panel***
   - ***Intelligent alerts emailed to the maintainer/owner isolates failure to panel or inverter.***
   - ***Graceful degradation (continues to operate with as few as 1 panel powering the inverter)***
   - ***Thermal survival mode (throttles power generation to survive abnormal ambient temperatures)***
   - ***Remote power throttling by the owner/ or power authority to mitigate over production***

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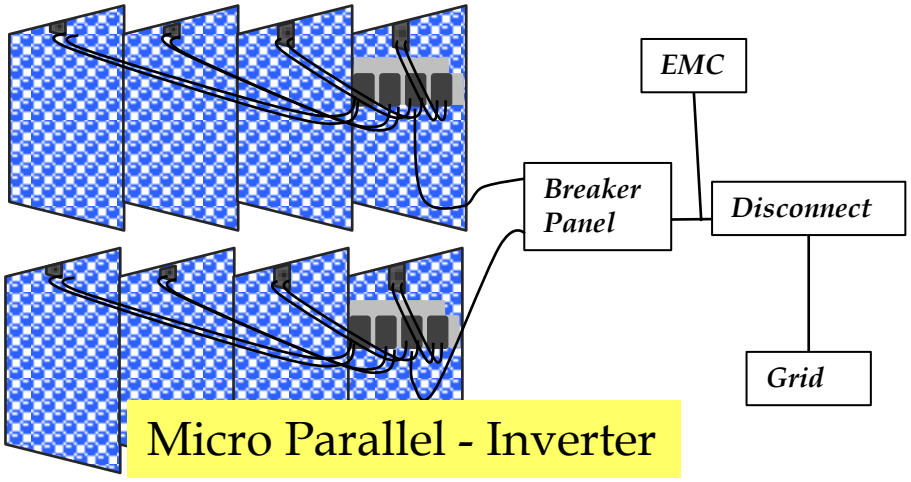
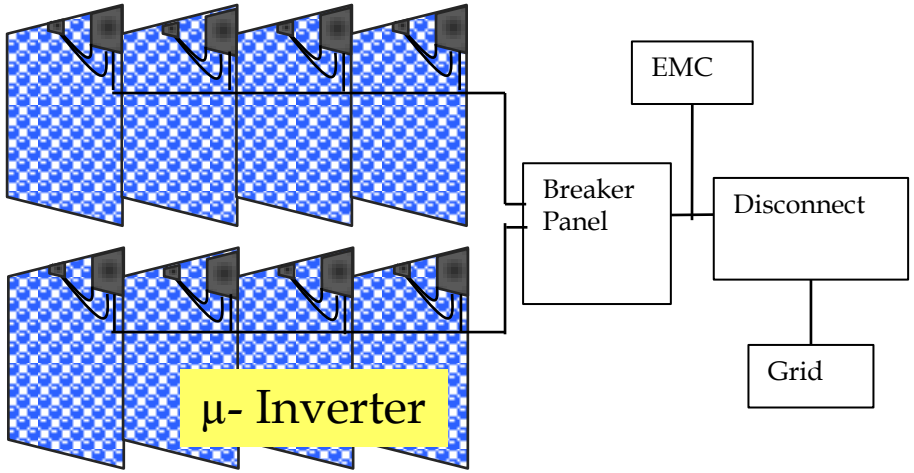
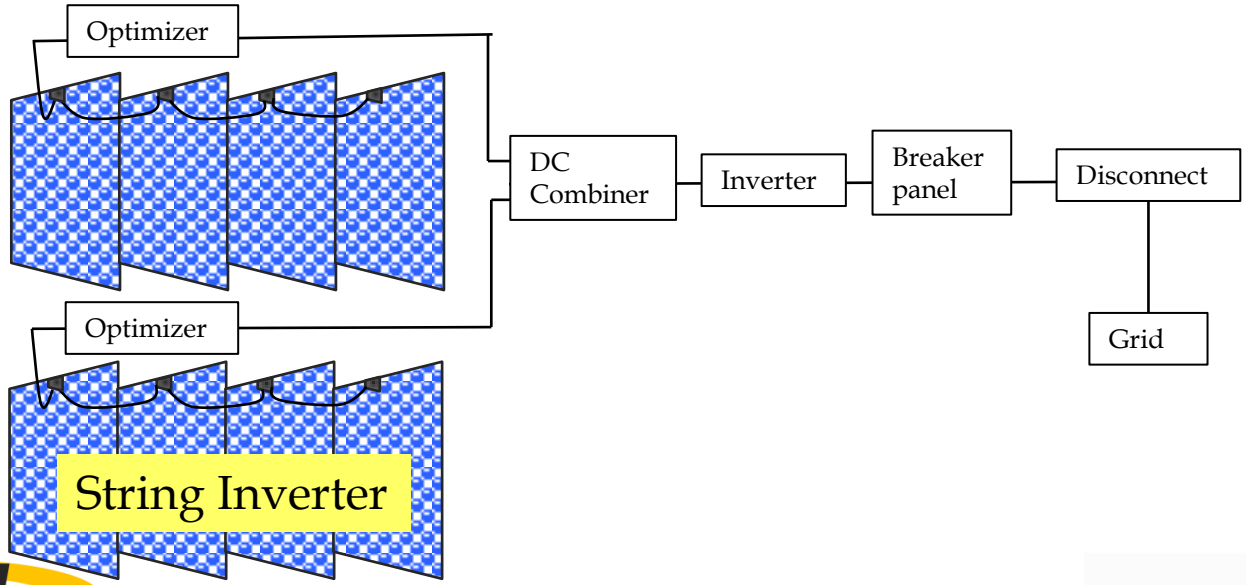
3 Inverter technology systems







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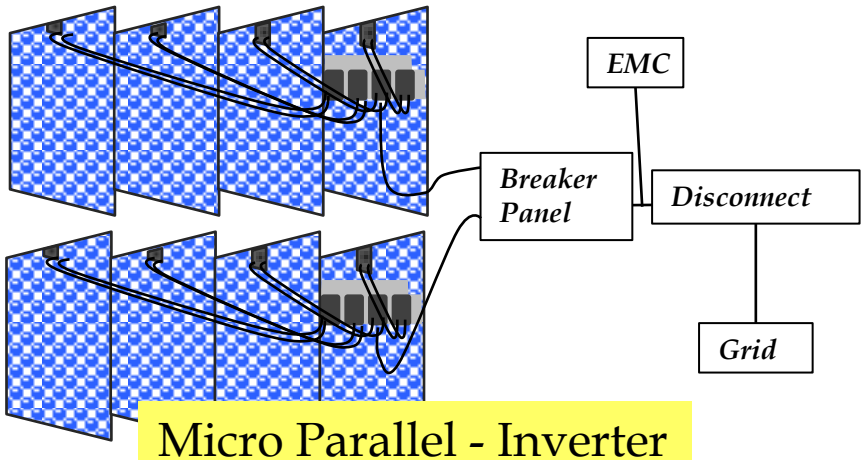
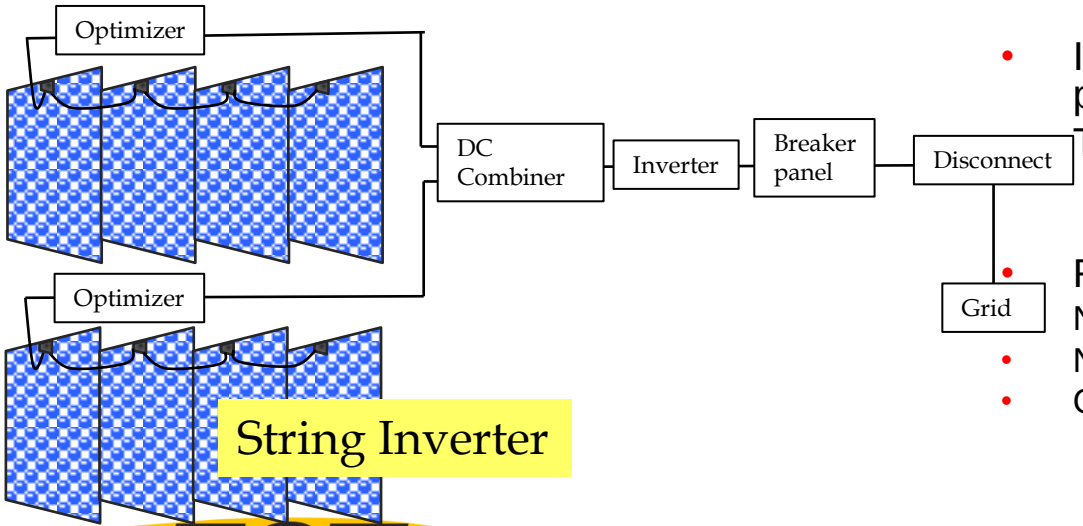
µ-parallel inverters are the solution when maintenance and cabling, and hardware costs are the driving factor



Micro Parallel - Inverter



String Inverter

Hardware, cabling and Maintenance costs Benefit µ-parallel inverters

- Self mapping array automatically maps inverter location to their physical location in the grid map
  - Time saving during installation
  - Eliminates "hunting the field" for the failed inverter or panel if mistakes occurred during a manual mapping
  - Goof proof cabling to panel
  - Each cable is a different length.
  - Position on the trunk cable automatically determined by the EMC.
- Intelligent alerts diagnostics and prognostics
- Tool less maintenance
  - Single handed blind install/ removal
  - Field reparable components
- Reduced cabling
- No need for DC combiner's
- No need for Optimizer's
- Graceful degradation when panels fail

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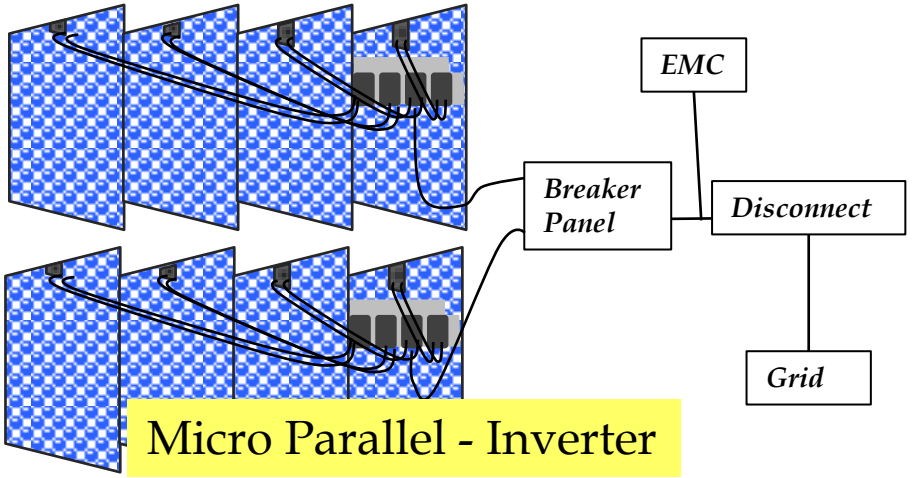
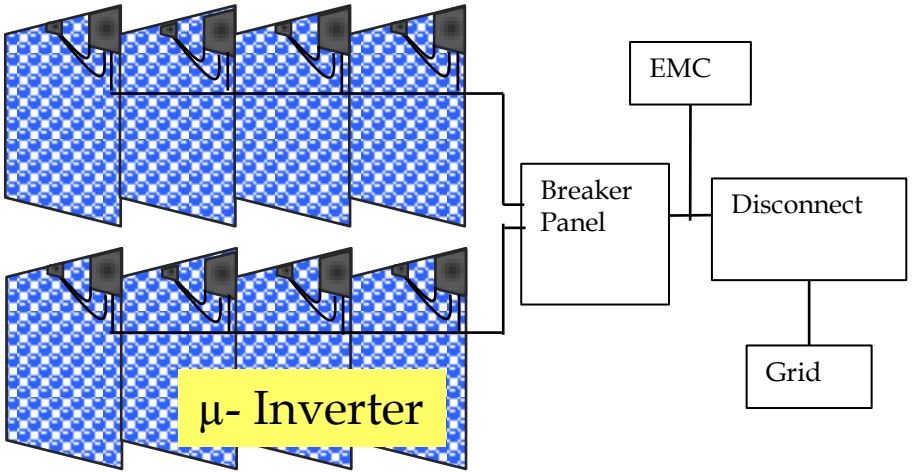
µ-parallel inverters are the solution when maintenance and installation costs are the driving factor





Installation and maintenance costs Benefit µ-parallel inverters

- ¼ the inverters to install
- Install where convenient
- Self launching web page and system setup guided by wizard launched from the EMC
  - EMC S/W wizard guides administration password and Internet setup.
  - EMC S/W wizard guides install.
- Self mapping array automatically maps inverter location to their physical location in the grid map
  - Time saving during installation
  - Eliminates "hunting the field" for the failed inverter or panel if mistakes occurred during a manual mapping
  - Goof proof cabling to panel
  - Each cable is a different length.
  - Position on the trunk cable automatically determined by the EMC.
- Simplified cabling system
  - 4 panels/ trunk
  - 1trunk / breaker
- Intelligent alerts diagnostics and prognostics
- Tool less maintenance
  - Single handed blind install/ removal
  - Field reparable components
- 4 x the panels monitored per EMC due to decreased inverter bandwidth requirement.
  - 1 µ-parallel inverters vs 4 µ-inverters

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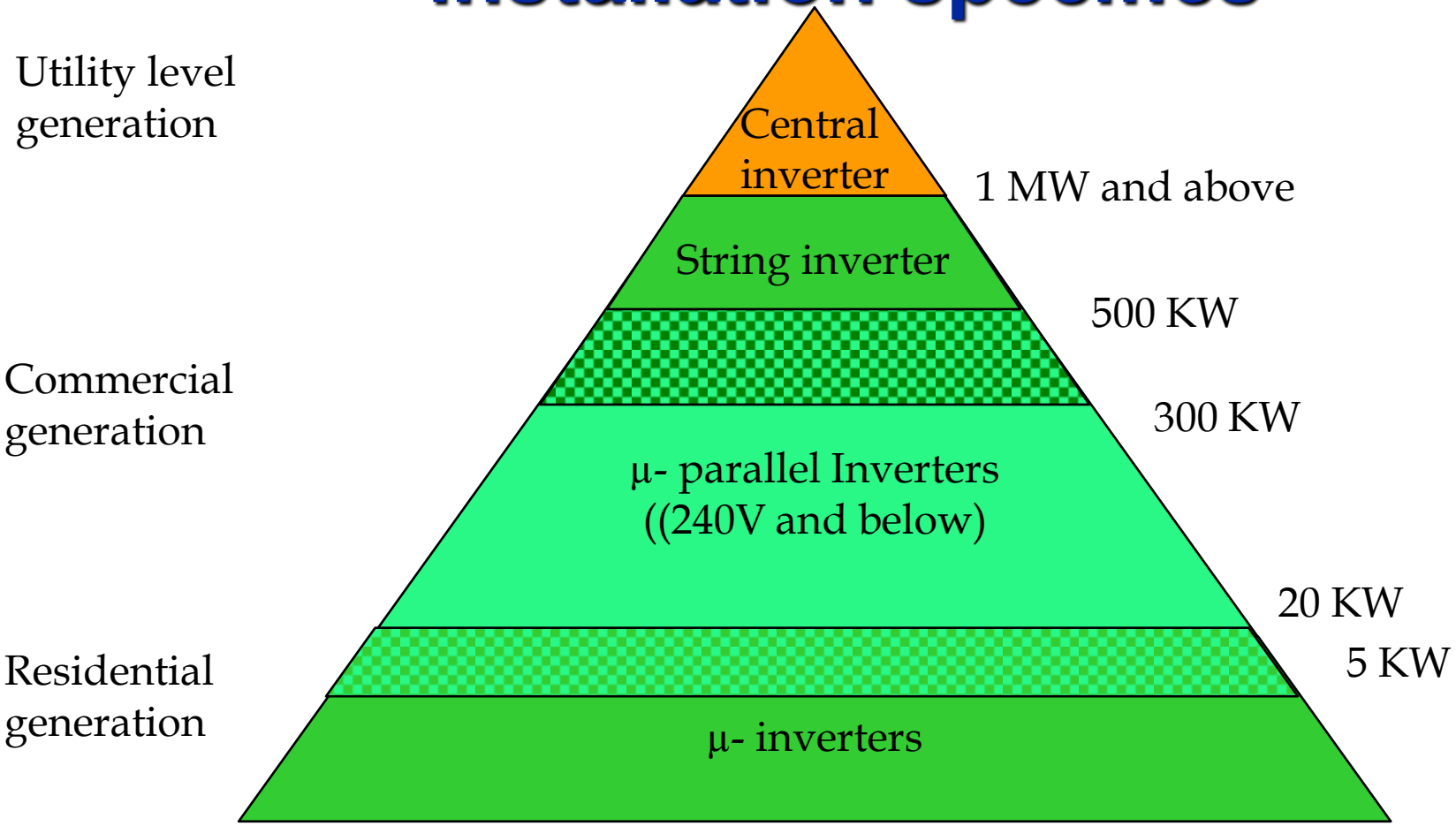
Technology selection based on installation specifics



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Three types Micro Grids

1. Off grid

- Provides power to a building with out connection to a utility power grid.
- Requires battery storage to serve as a ballast to the fluctuations of solar generation.
- Requires a wave form generator of the same size as the anticipated load that is incorporated into an off grid only inverter or a separate wave form generator where the inverter can be used in a grid tied application.
- Requires a fueled backup to recharge batteries or operate during extended rainy seasons where a solar drop out lasts long enough to deplete the batteries
- Requires a transfer switch to sense when the solar generation is below a threshold during emergency power generation to start the generator and disconnect the emergency wave form generator.

2. Grid tied

- Provides supplements solar power to a building that is tied to the utility power grid.
- Shuts off when the grid fails or browns out.
- Critical safety feature that allows power crews to safely work on restoring power

3. Grid tied with automatic emergency power

- A grid tied system with automatic transfer switches automatically disconnects from the grid when the grid voltage drops below a set level and then turns on a battery powered wave form generator of the same size as the anticipated load that allows the grid tied system to behave as an off grid system

Governing Electrical codes for Grid tied and emergency power

Governing Codes (US)
NFPA 70/ NEC Article 690 - Solar Photovoltaic Systems –
Building Codes – ICC, ASCE 7-05
Uniform Solar Energy Code – ICC
UL Standard 1703, Flat-plate Photovoltaic Modules and Panels
Safety and EMC
Anti Islanding UL1741
Anti Islanding IEEE1547
CAN/ CSA-22.2 no. 107.1-01
IEC / EN 62109-1 , 62109-2
Immunity for industrial environments Reference IEC / EN 61000-6-2

Grid Code Compliance (Ca,CSA & DE)
C-tick
California energy commission CEC
Grid Code Compliance IEEE 5047
Grid Code Compliance AS 4777:2005-2&3
Grid Code Compliance VDE-AR-N 4105
Grid Code Compliance VDE-V-0126-1-1/ A1
Grid Code Compliance G83-2
General Use Power Supplies CSA C22.2 No. 107.1
MICRO-03-I-OUTD-US-208/240

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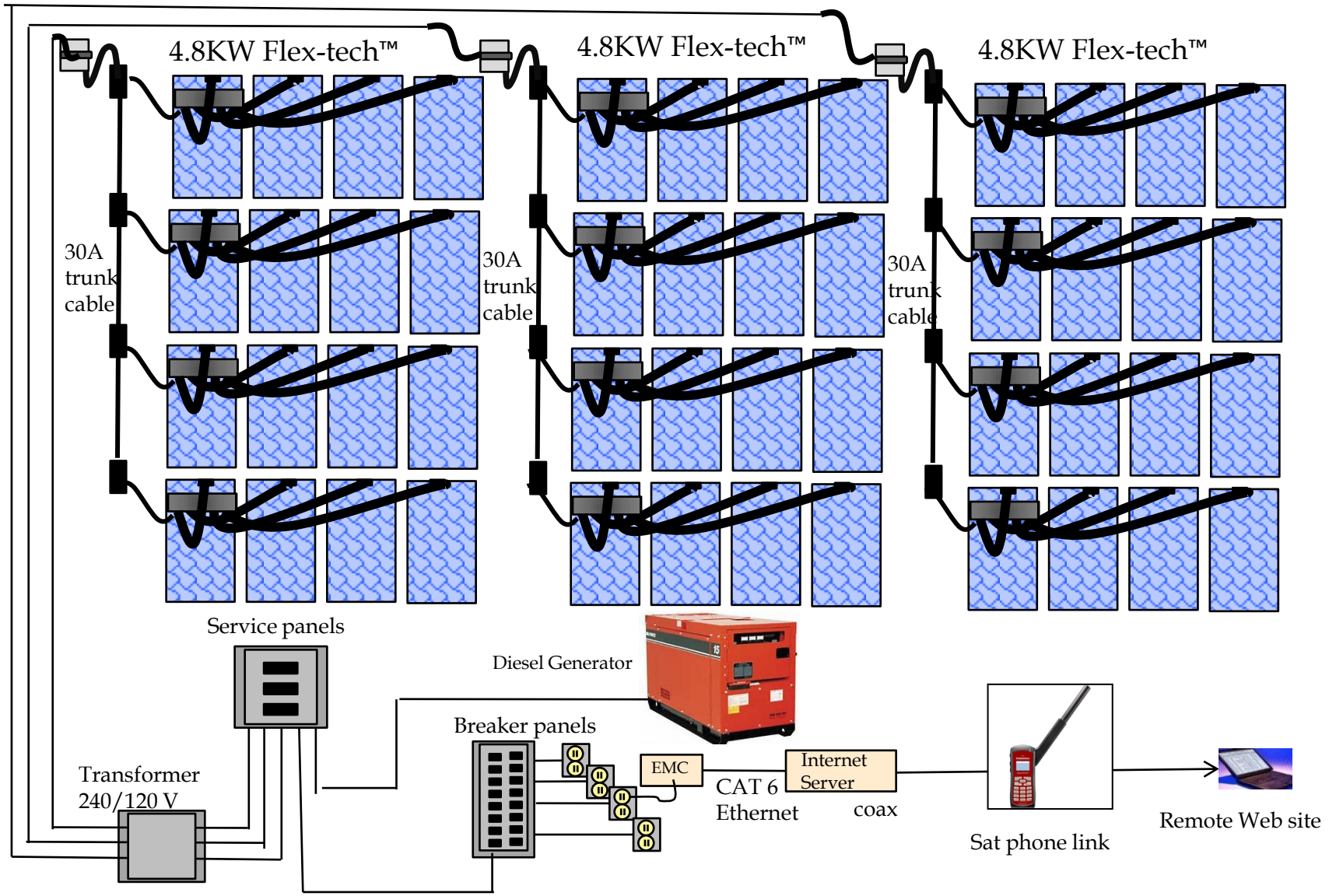
Off grid, micro grid architecture



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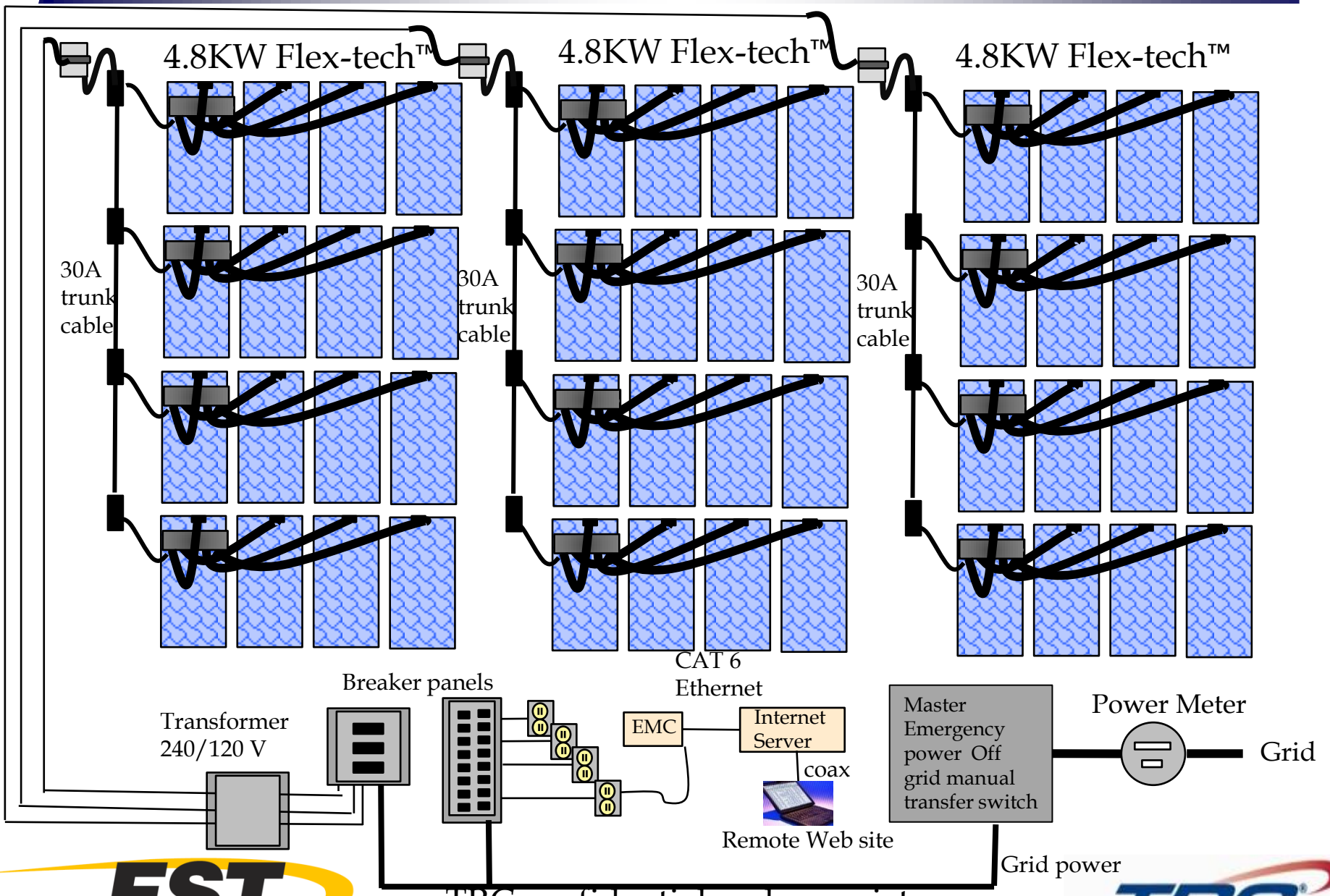
Grid tied micro grid architecture



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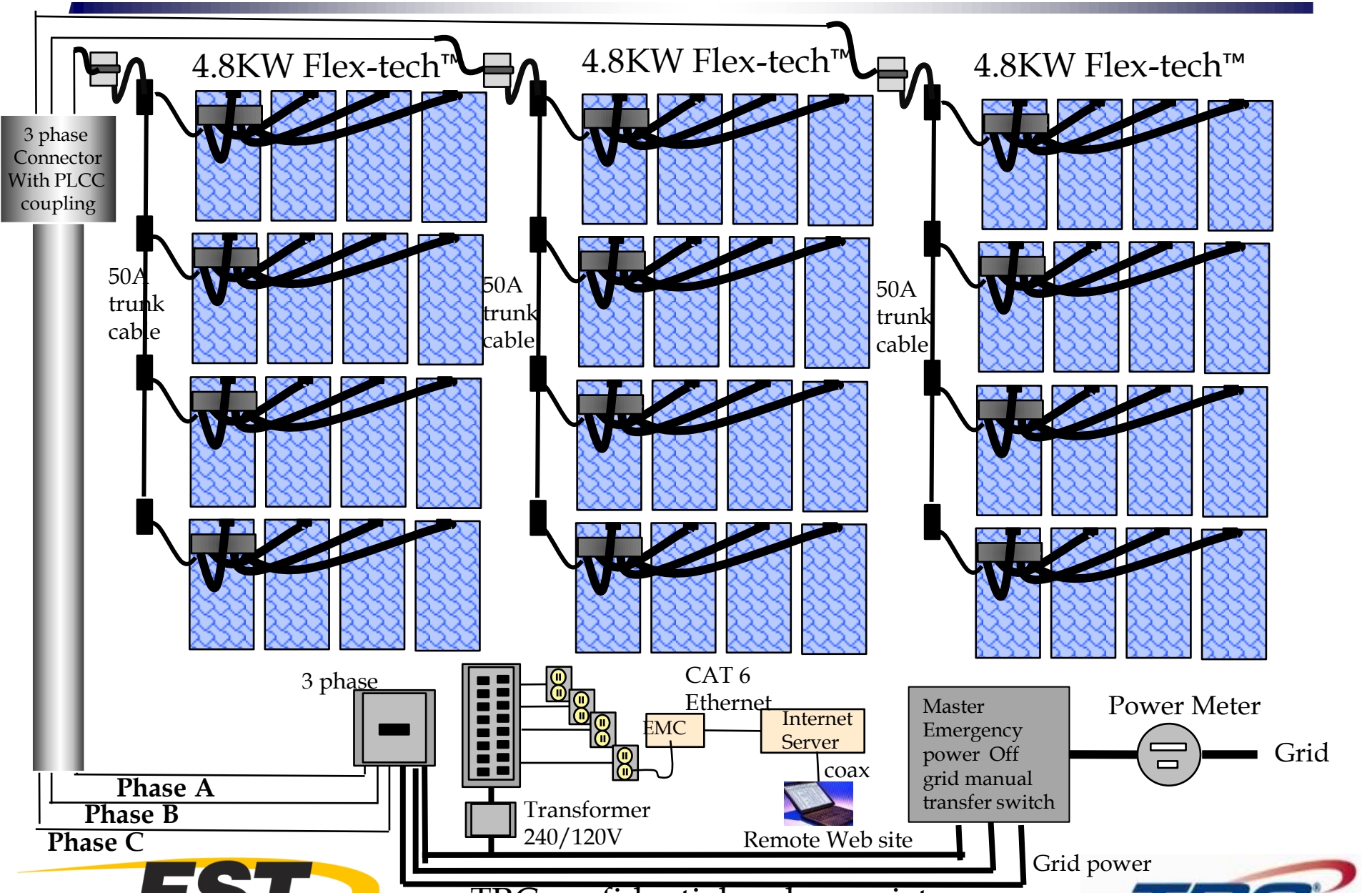
3 Φ grid tied micro grid architecture



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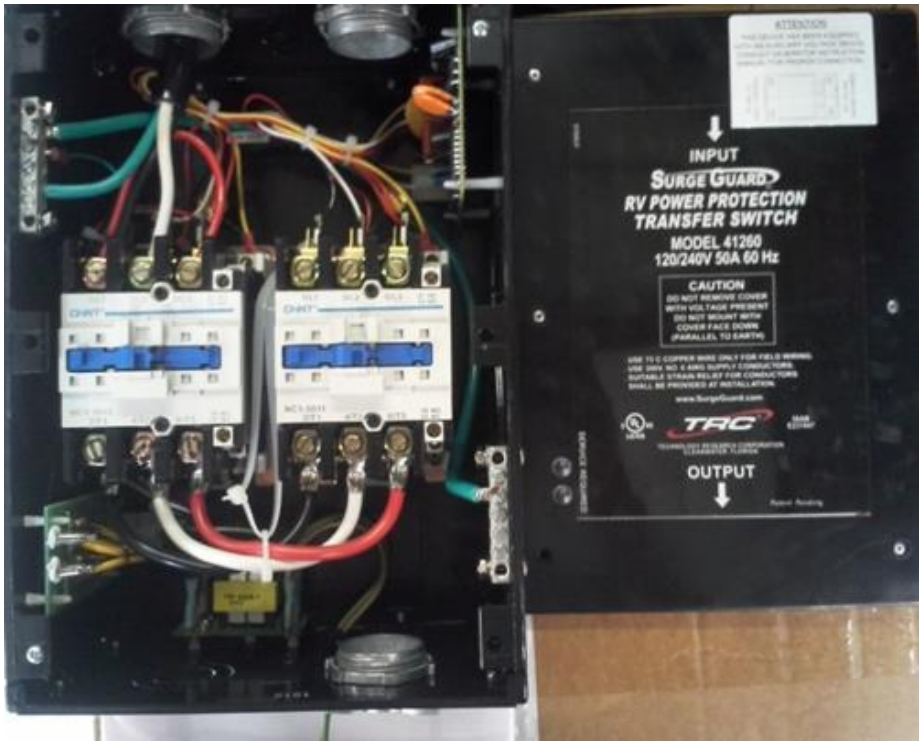
New transfer switch technology allow the design of reconfigurable grid tied systems that provide emergency power

- Smart Phase™ Automatic transfer switches
  - generator start (under voltage detection),
  - Load shedding (over voltage)
  - generator start inhibit when voltage is within operating range.



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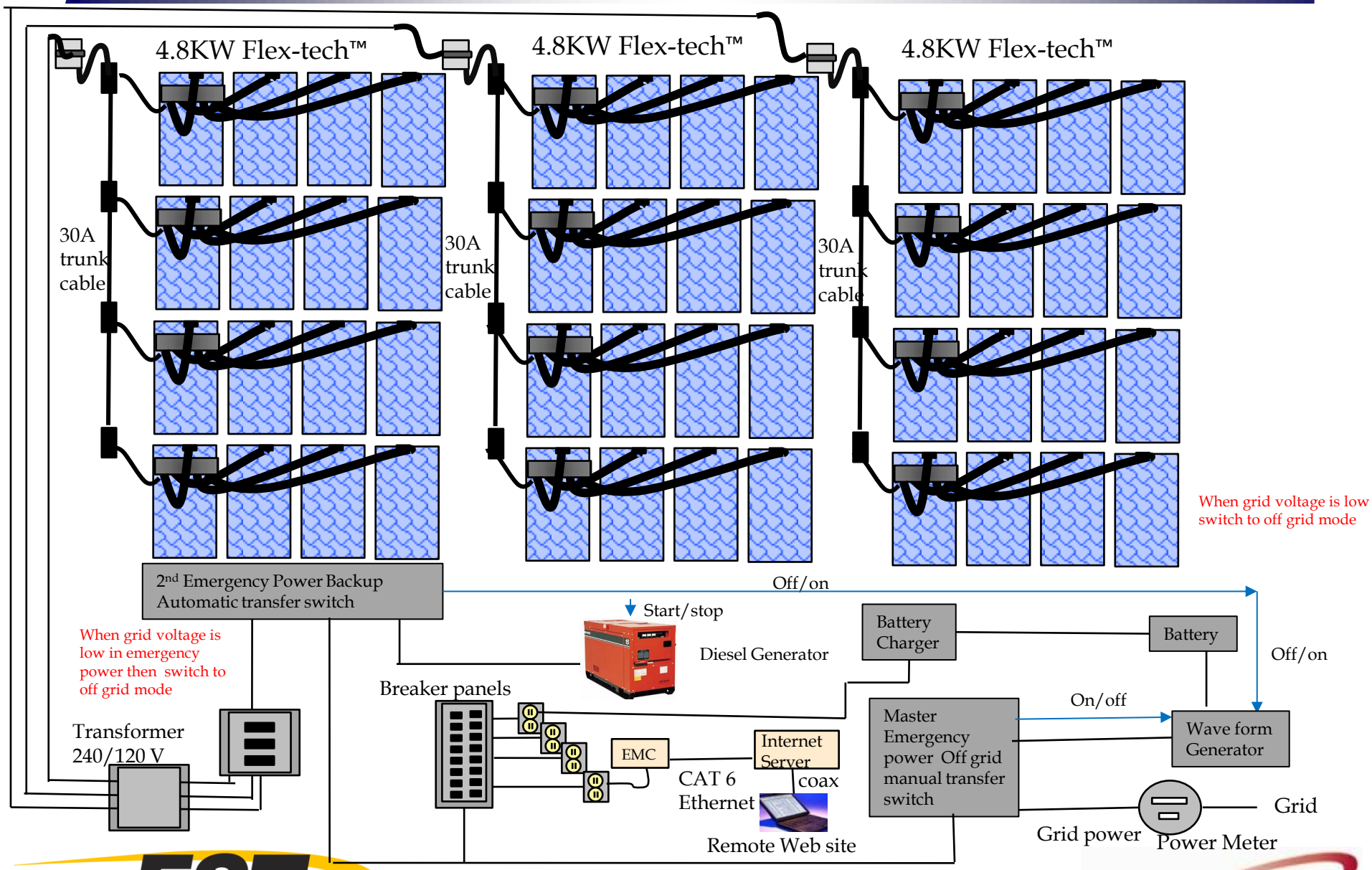
Grid tied micro grid with emergency power architecture



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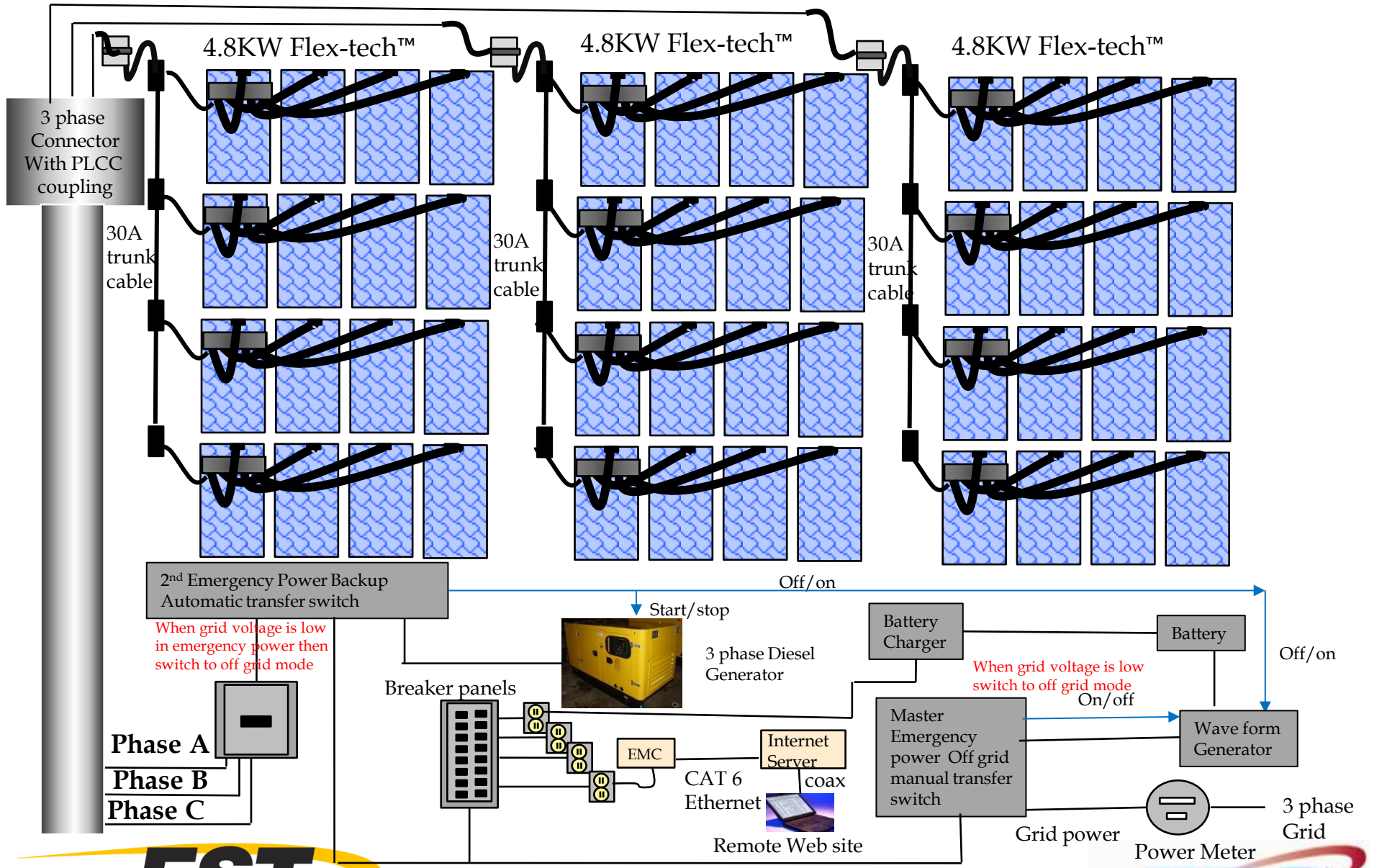
3 Φ Grid tied micro grid with emergency power architecture



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µ-parallel inverters

- A new paradigm in inverter technology
- Developed to eliminate hardware, and reduce installation and maintenance costs

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Taxonomy of a PV investment

*** Department of Energy's Lawrence Berkeley National Laboratory (Berkeley Lab).**

Residential and small commercial systems <10kW

- Framing
  0.68/W 1.10/W
- Panels
  0.70/W 1.00/W
- Inverters
  0.70/W 1.00/W
- Installation
  1.82/W 2.8/W
- Total cost $
  3.90/W 5.90/W

Installation is largest cost driver by a factor of 2 to 3

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Micro Parallel Inverters Summary

System sizing

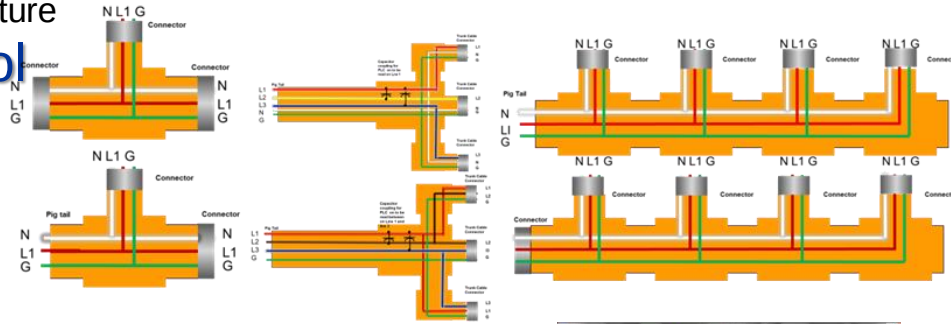
- 300KW and below grid tied or off grid system
  - Cost trade begins to swing in favor of String inverters
  - 1000 Panels, 250 inverters, 63 trunk cables, 1 EMC
  - 1.5 acre of land with spacing

Performance

- 1.2KW instantaneous and 1.1KW continuous output power.
- 120/240V 1 Phase AC / 208V/240V 3 Phase AC
- Robust performance and graceful degradation
  - Up to 4 panels per inverter. (operate with as few as 1channel.)
  - AC power (no need for DC combiner boxes.)
  - Survival mode; throttles generation for high temperature

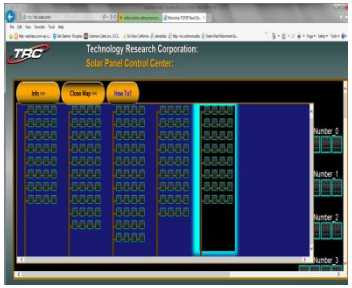
Electricity Monitor and Control

- Smart grid data collection, self-diagnostic, alerts
- Web-based reporting,.
- Remote control and upgrades.



Maintenance & installation

- Single handed blind mount installation.
- Automatic grid mapping of panels and inverters
- Home installation (16 panels, 4 inverter 1 trunk) 4.8KW
- Commercial 3Φ (48 panels, 12 inverter 3 trunk) 14.4KW



Trunk Cables

- Simplified installation I trunk per service breaker
- Integrated ground
- Y and Δ Connectors

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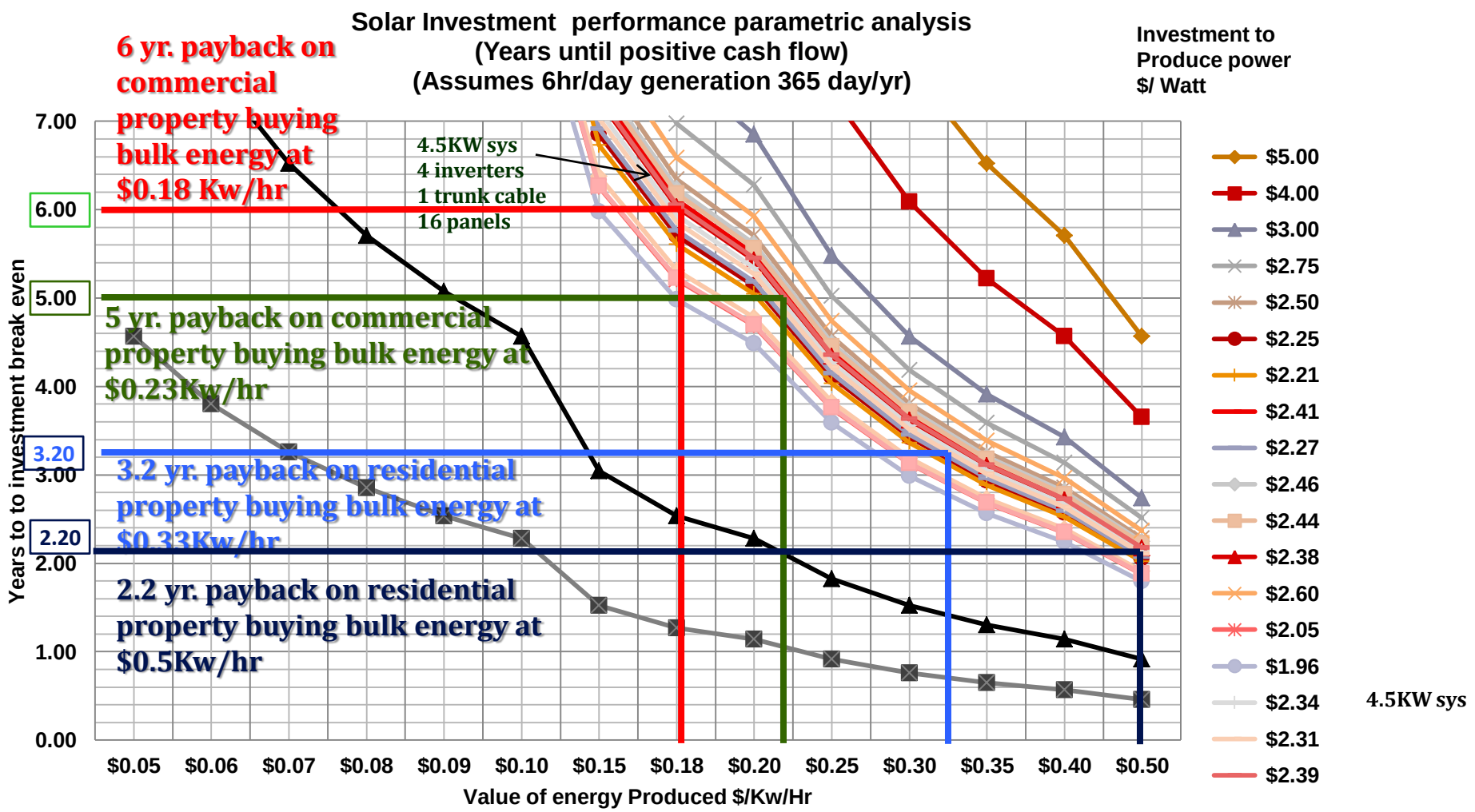
Solar Investment payback

- Pay back time(yr) =
  - investment for power production($/watt)
  - x 1000(w/kw)
  - x value of energy produced($/Kw/hr)
  - x hrs. of generation (hrs./yr)
- Assumptions for hours of generation
  - 6hr/day generation
  - 365 day/yr
- System content;
  - Panels,
  - Roof top mount
  - Trunk cables
  - Inverters
- Installation and tax credits not excluded
  - Tax credits are handled as a deduction. On the curves
  - US average tax credits for 2013 were approximately $0.60 per watt.
- Installation costs estimated by adding in on the curves
  - $1.80 to $2.80 per watt
  - Need to ratio labor costs from US to installing country

Pricing Study Generic for 5KW module at specific energy rates



Pay back time(yr) = investment for power production ($/watt) x 1000(w/kw) x value of energy produced($/Kw/hr) x hrs of generation (hrs/yr)

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Application Brief

TRC SmartPhase™

Introducing SmartPhase™ 1.2 Kilowatt Grid Tied Micro Parallel Inverter

Technology Research Corporation, a subsidiary of Coleman Cable, Inc., has designed and developed a new class of inverter, the Smart Phase™ Micro Parallel Inverter. These inverters are designed around the concept of easing the ergonomic burden of installation, diagnostics and maintenance. The inverters mount to either the solar panels or framework, minimizing the impact of NEC article 690 and team composition (see Article 690.6 AC modules).

A micro parallel inverter has the safety and data of an AC micro inverter with the installation convenience and placement flexibility of a DC string inverter. Inverter performance, health, and status are relayed via power line communication (PLC) to an Energy and Monitoring Controller (EMC) which updates a self-launching website for remote viewing and data extraction. The data resolution is sufficient to trace performance and faults to individual panels, inverters, and modules. The patent pending (utility patents filed) architecture has four independent channels per inverter. The inverter remains operational, generating power and relaying performance, health, diagnostics data and alerts to the maintainer with as few as one solar panel and one inverter channel functional. The software architecture allows the inverter's firmware and the EMC software to be remotely upgraded buttressing installed units against obsolescence.

SMARTPHASE.

SMARTPHASE. Inverter Characteristics

- 1.2kW instantaneous and 1.1kW continuous output power.
- Robust performance and graceful degradation up to 4 panels per inverter. Continues to operate with as few as 1 panel and 1 channel.
- Standard cabling and connectors are used and the AC inverters eliminate the need for DC combiner boxes.
- Easy single handed blind mount installation.
- Smart grid data collection; web-based reporting, control, and alerts.
- Self-diagnostics.
- Remote software and firmware upgrades.
- 120/240V 1 Phase AC
- 208V 3 Phase AC

To learn more about Smart Phase™ 1.2 Kilowatt Grid Tied Micro Parallel Inverter please call: 1-800-780-4324

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INPUT DATA	
Recommended input power	210-300 W
Maximum input DC voltage	48 V
Peak power tracking voltage	25-50 V
Operating range	25-50 V
Start voltage (min./max.)	25-50 V
Maximum DC short current	15 A
Maximum input current	13 A
OUTPUT DATA	
Peak output power	1.2 kW
Rated continuous power	1.1 kW
Nominal current (A) rms @ Nominal duration	4.58 @ 240V, 5.29 @ 208V, 9.16 @ 120V
Nominal voltage/range (V)	240/211-264, 120/95-135
Nominal frequency/range Hz	60/59.3-60.5
Extended frequency/range Hz	57-62.5
Power factor	>0.95
Maximum units per 30A branch circuit	24 panels, 6 inverters @ 240V
Maximum output fault current (A)	80mA rms for 6 cycles
Maximum units per 20A branch circuit	16 panels, 4 inverters @ 240V
THDi (at rated power)	<5%
EFFICIENCY %	
CEC weighted efficiency	96
EURO efficiency	95
Peak inverter efficiency	96
Static MPPT efficiency weighted ref EN50530	99.4
Night time power consumption (mW max)	<0.005 W
SIZE, WEIGHT & TEMPERATURE	
Width (mm)	39"
Height (mm)	6.5"
Depth (mm)	0.75"
Weight	8 kg
Ambient temperature range	-40°C to 65°C
Operating temperature range internal	-40°C to 85°C
Cooling	Convection
Enclosure environmental rating	NEMA-6
Ingress protection (IP)	IP 66
KEY FEATURES	
PV module cell compatibility	60/72
Communication	PLC
Integrated ground equipment	Provided in cable
Monitoring	Self-launching web portal
SAFETY & EMC	**STANDARDS COMPLIANCE**
Safety and EMC	CAN/CSA-22.2 no. 107.1-01
Anti-islanding	UL1741
Anti-islanding	IEEE-1547
FCC	part 15 class B

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