2016 IEEE / MCPG meetings cycle,

Kameel Andrawos
Director, Power Systems
Schneider Electric

Nashville, TN

Schneider Electric

UPS Topologies

● UPS Construction

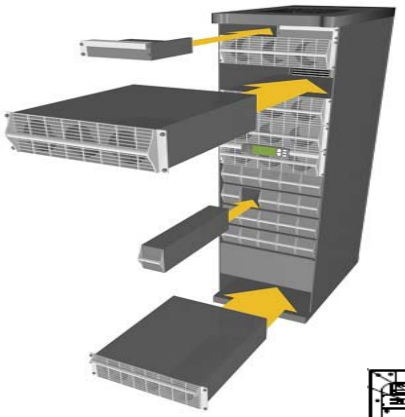
- ➢ Modular construction
- ➢ Traditional with plug-in assemblies

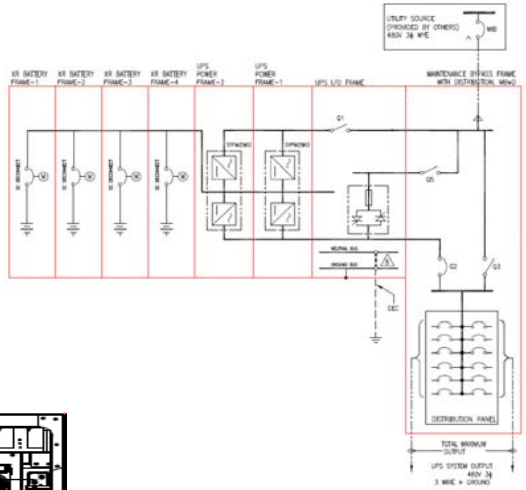
● UPS Configuration

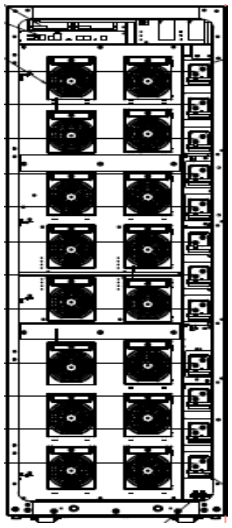
- • Single Module
- • Parallel with Centralized static switch
- • Integrated parallel

● UPS Topology

- • Transformless UPS
- • UPS with transformers (input and output)





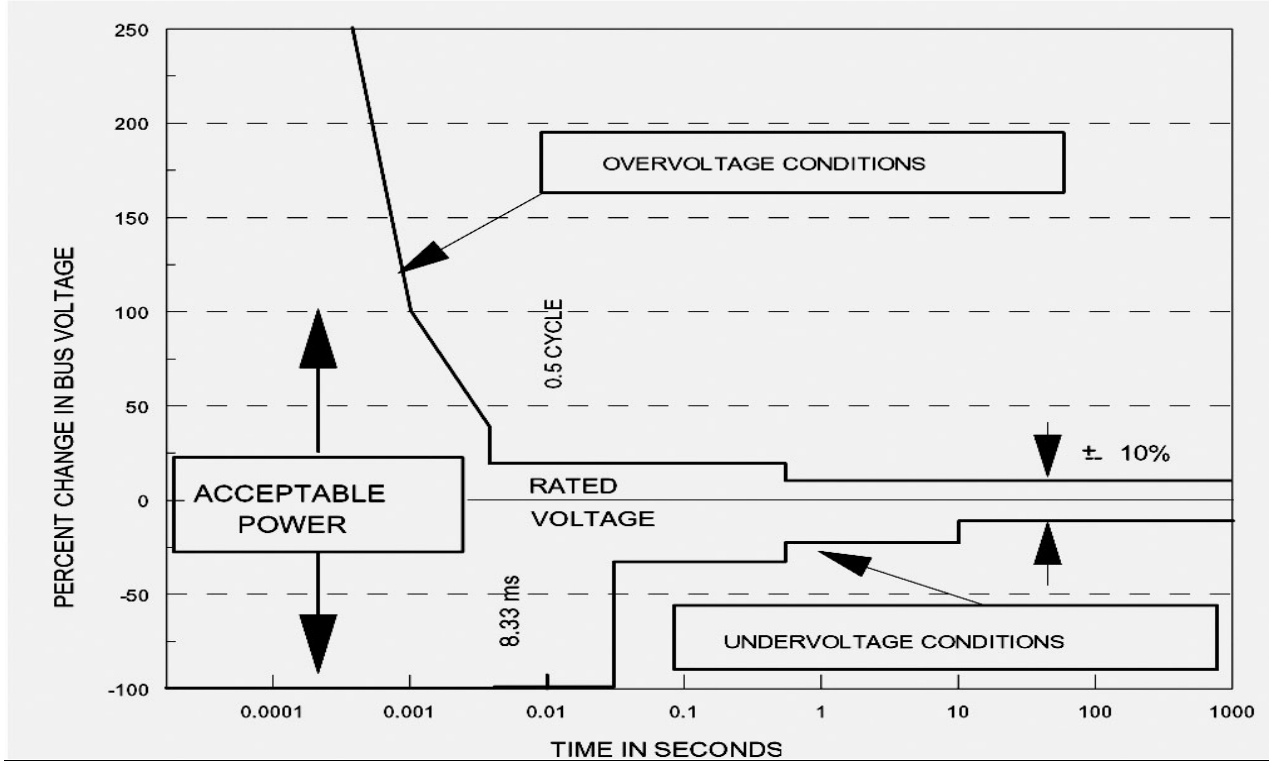


UPS DEFINITION

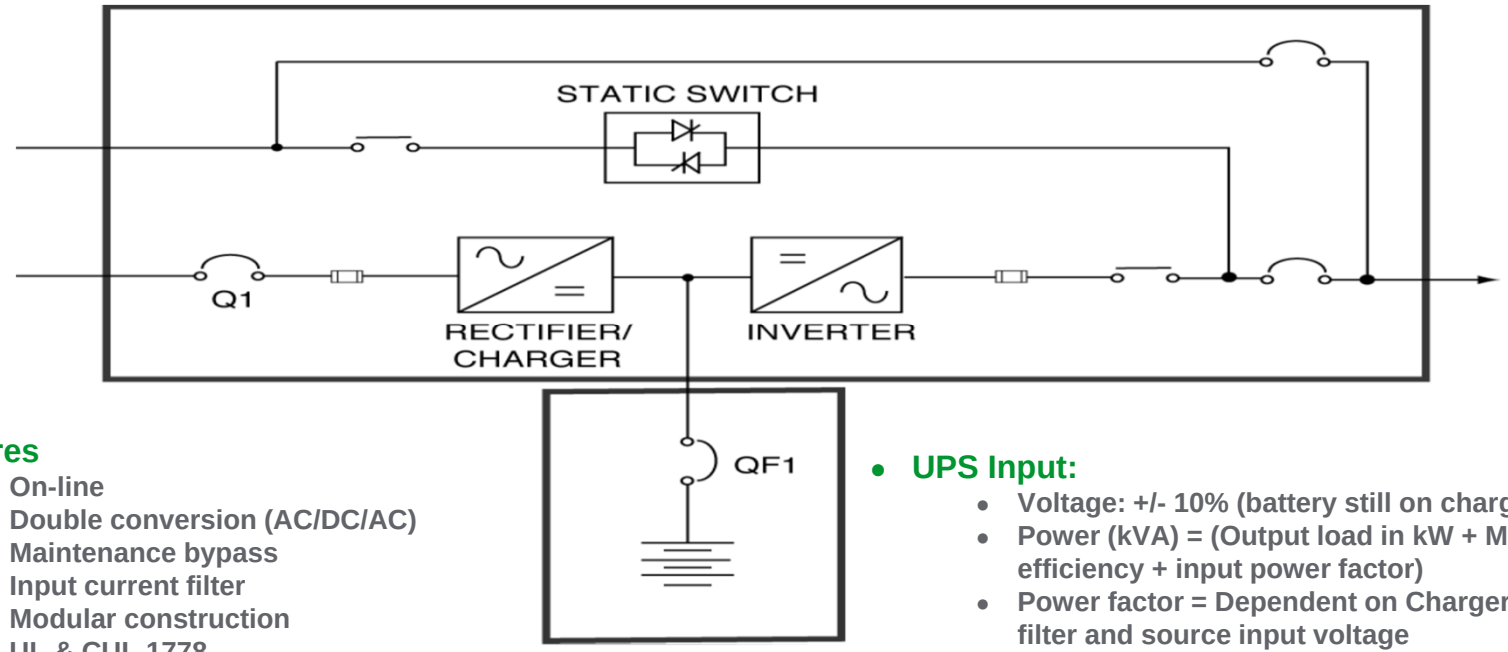
- **Power Protection**
  - Provides power back-up during power outage
- **Power Conditioning**
  - Nominal output voltage with 1% regulation (some vendors specify +/- 0.5%)
  - Nominal output frequency with 0.1 Hz regulation
  - Output voltage distortion (VTHD) 5% maximum

POWER PROBLEMS

- **Power Problems:**
  - External causes (utility outages)
  - Internal causes (CB trip, inrush, bus failure)
- **Power Problems:**
  - Black-out, Brown -out, Sags, Swells, Surges, Transients, Waveform Distortion



On-Line UPS (Standard Features)



- **Features**
  - On-line
  - Double conversion (AC/DC/AC)
  - Maintenance bypass
  - Input current filter
  - Modular construction
  - UL & CUL 1778

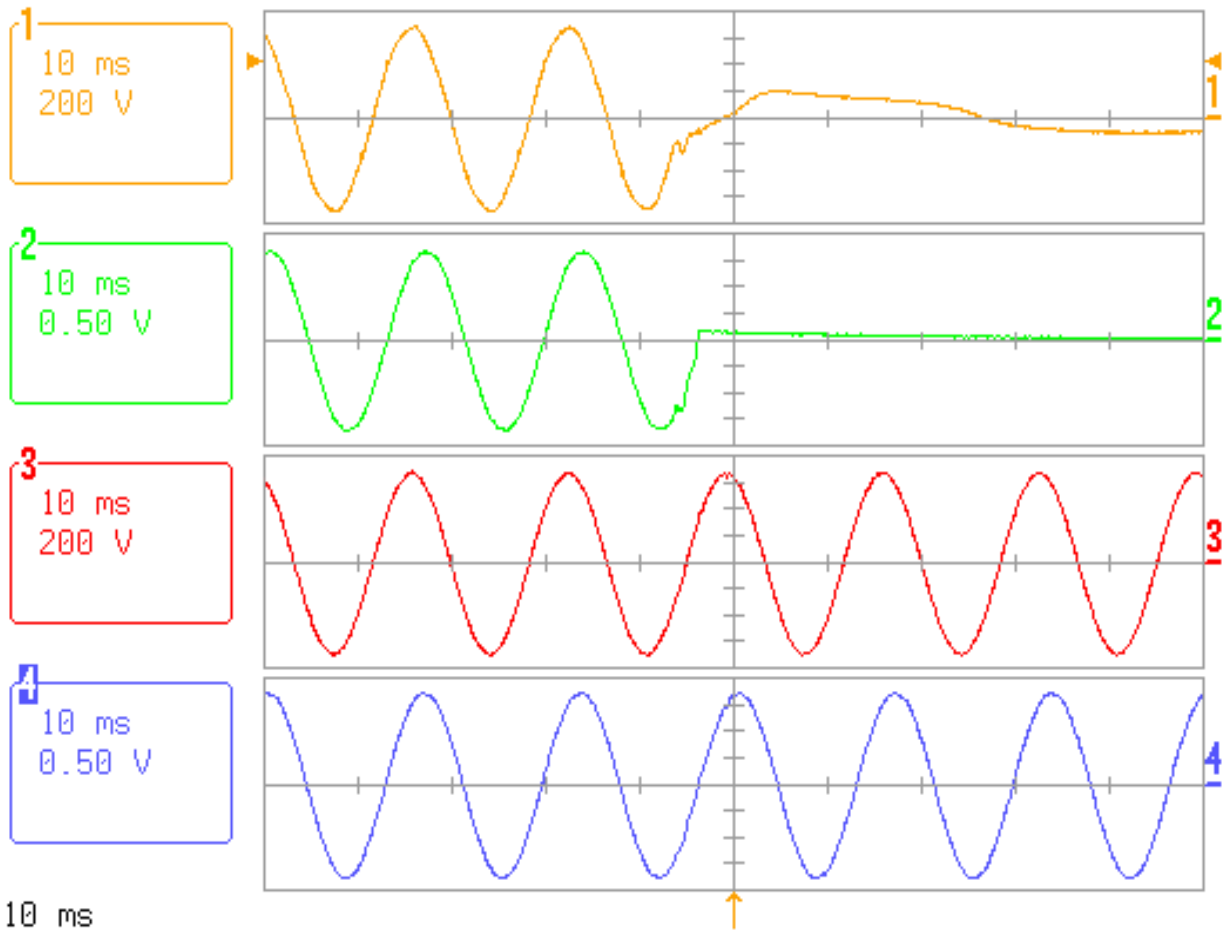
- **UPS Input:**
  - Voltage: +/- 10% (battery still on charge)
  - Power (kVA) = (Output load in kW + Module efficiency + input power factor)
  - Power factor = Dependent on Charger/Input filter and source input voltage
  - Current = Input power. UPS is provided with 2nd step input current limit (limits the current to any set point).
- **Bypass input:**
  - Voltage = nominal +/- 10%
  - Current = Load current (no current limiting)

Output:

Voltage = Nominal +/- 1%
Current = load current
Power = rated kVA and rated kW (either parameter should not be exceeded).
Power factor = load power

▪Battery – please refer to battery page

Battery Operation



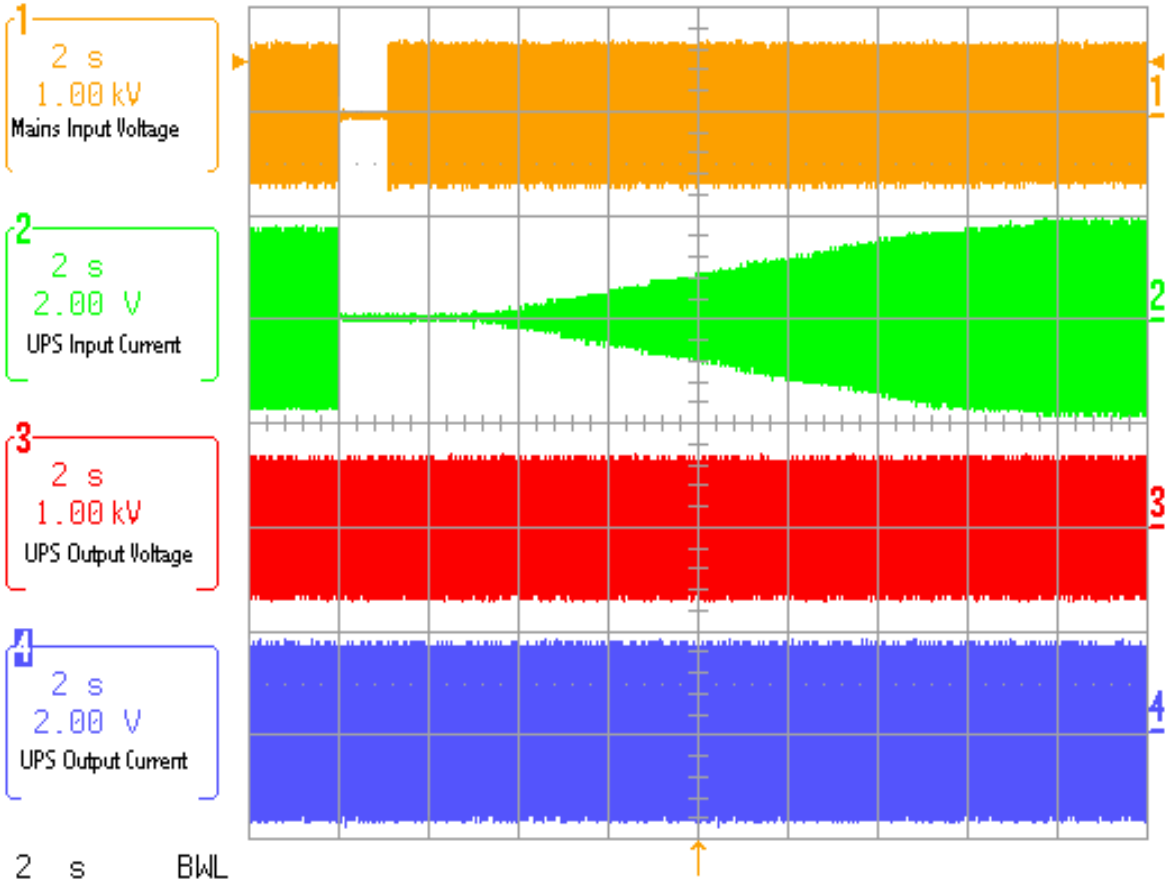
Input Voltage Ph A

Input Voltage Ph B

UPS output Voltage Ph A

UPS output Voltage Ph B

UPS Walk-in Cycle



Input Voltage

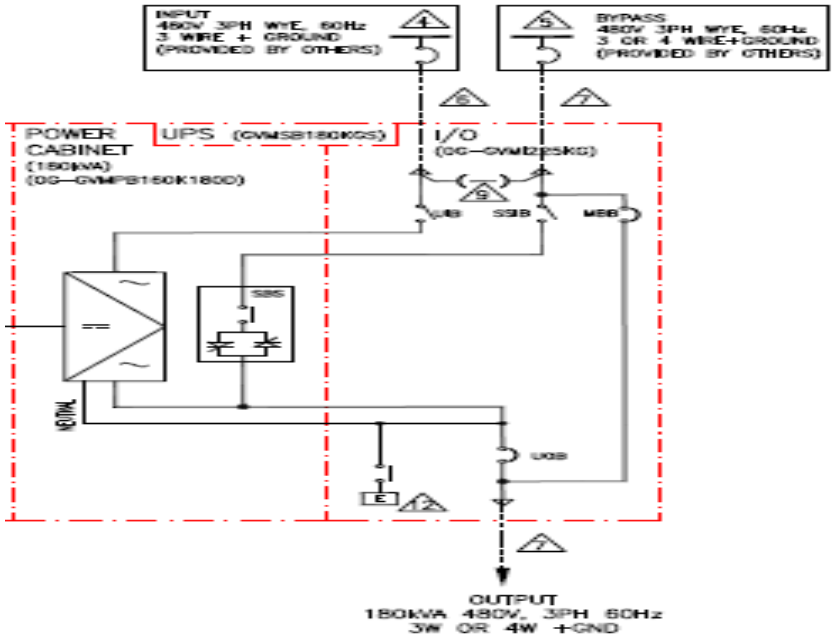
Input current

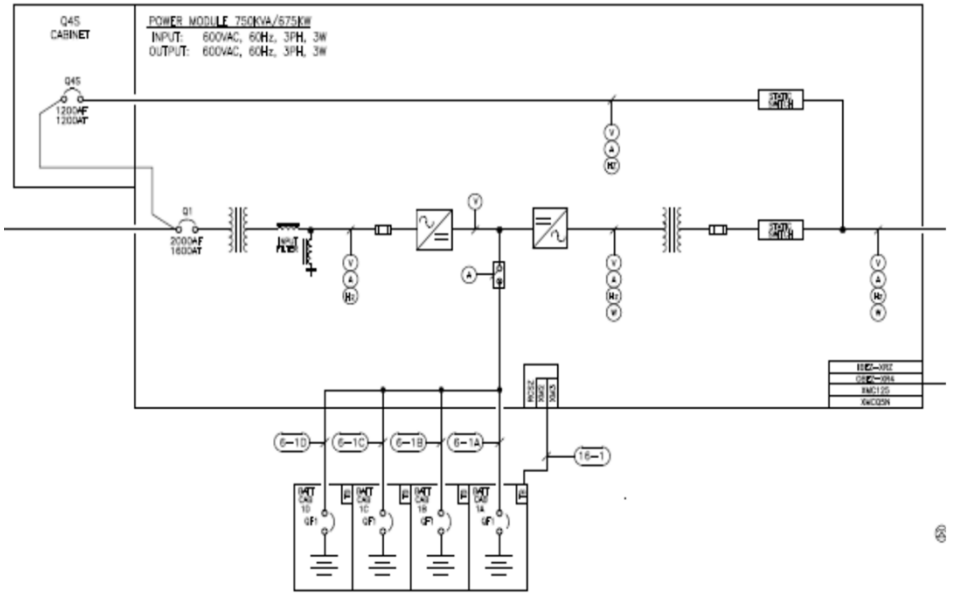
UPS output Voltage

UPS output current (load)

Transformerless Product

	Transformerless Topology				
	Double conversion (from 10 10 1500 kW)	**Delta conversion (400 to 1600 kW)**	**6-pulse rectifier (double conversion) 300 to 500 kVA**	**12-pulse rectifier (double conversion) 500 to 1125 kVA**	**Comments**
Input Transformer	NO	YES	NO	YES	1. 10 to 1500 kW units have no transformers. It is the true definition of "transformless" Topology. 2. Delta conversion has a Delta Transformer (this is not an input isolation transformer). 3. 6-pluse has no input transformer. It has output transformer 4. 12-pulse - True isolation transformer (DC bus is floating). It has output transformer.
Inverter/output Transformer	NO	NO	YES	YES	



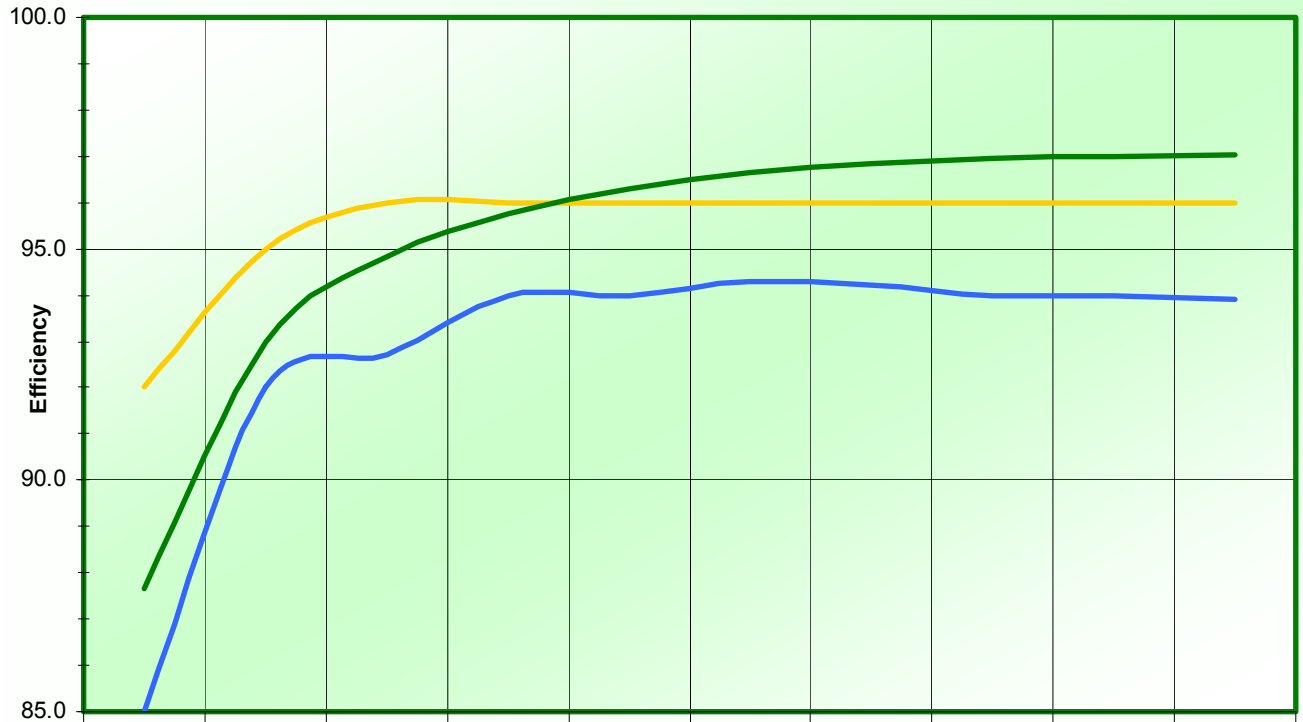


Transformerless Product

	Transformers Topology	
	Weak points	**Benefits**
Input isolation Transformer:	a. Big b. Expensive c. Reduces overall efficiency	a. Provides isolation to the DC bus (floating DC bus – protection against DC ground faults). b. Provides protection against input voltage surges c. Provides impedance isolation to limit fault current to rectifier/charger
Inverter/Output isolation transformer	a. Big b. Expensive c. Reduces overall efficiency d. ECO mode (with inverter off) can not be applied to this topology. e. Concern about circulating current back to the main input source. Caused by unbalance current between modules in parallel system	a. Provides isolation to the load (total isolation) b. Separately derived source c. Provides protection to the inverter (reverse feed) d. Summing transformer for voltage regulation e. Eliminate circulating current caused by unbalance between module in parallel system (unbalance flows to UPS module output transformer.

Schneider Electric UPS

Efficiency Comparison



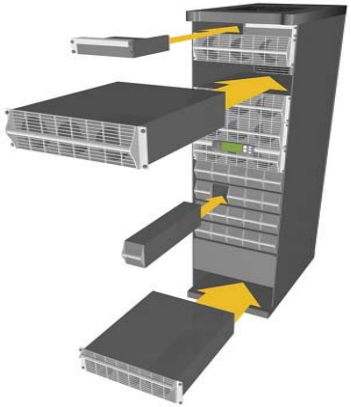
	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
EPS 8000	85.0	92.0	92.7	94.0	94.0	94.3	94.2	94.0	94.0	93.9
SYPX	92.0	95.0	96.0	96.0	96.0	96.0	96.0	96.0	96.0	96.0
SYMW	87.6	93.0	94.9	95.8	96.3	96.6	96.8	96.9	97.0	97.0

Load

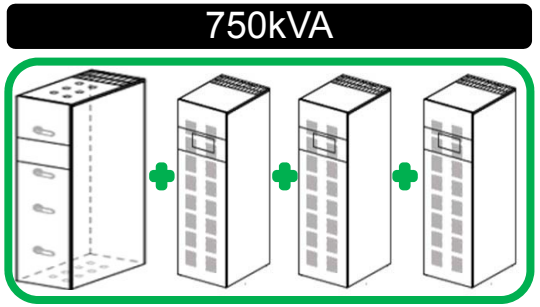
Modular vs. Assembly Design UPS

UPS with Plug-in assembly

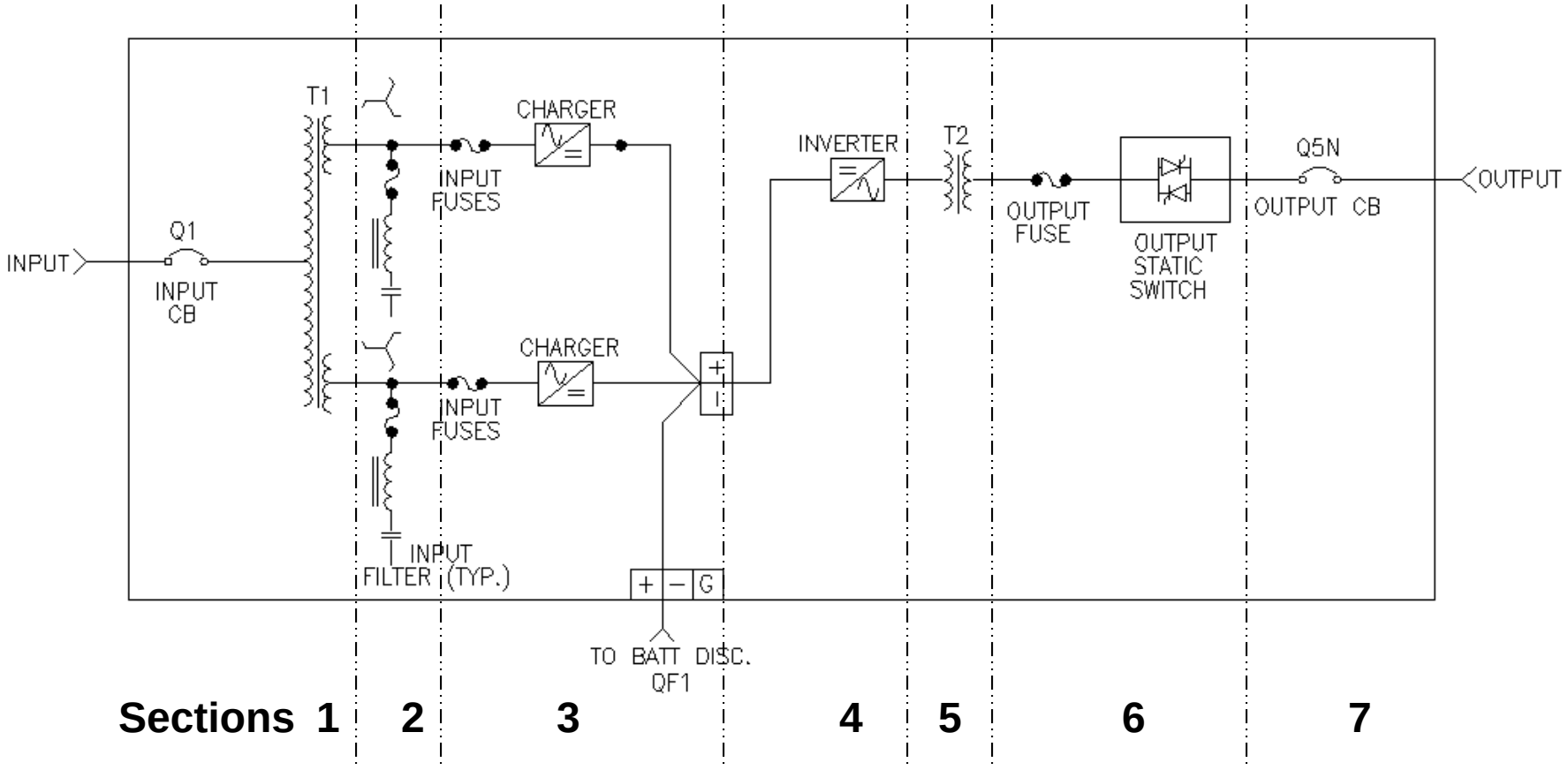
Modular UPS with Plug-in Power Modules



Modular UPS with Power cabinets



Module Losses



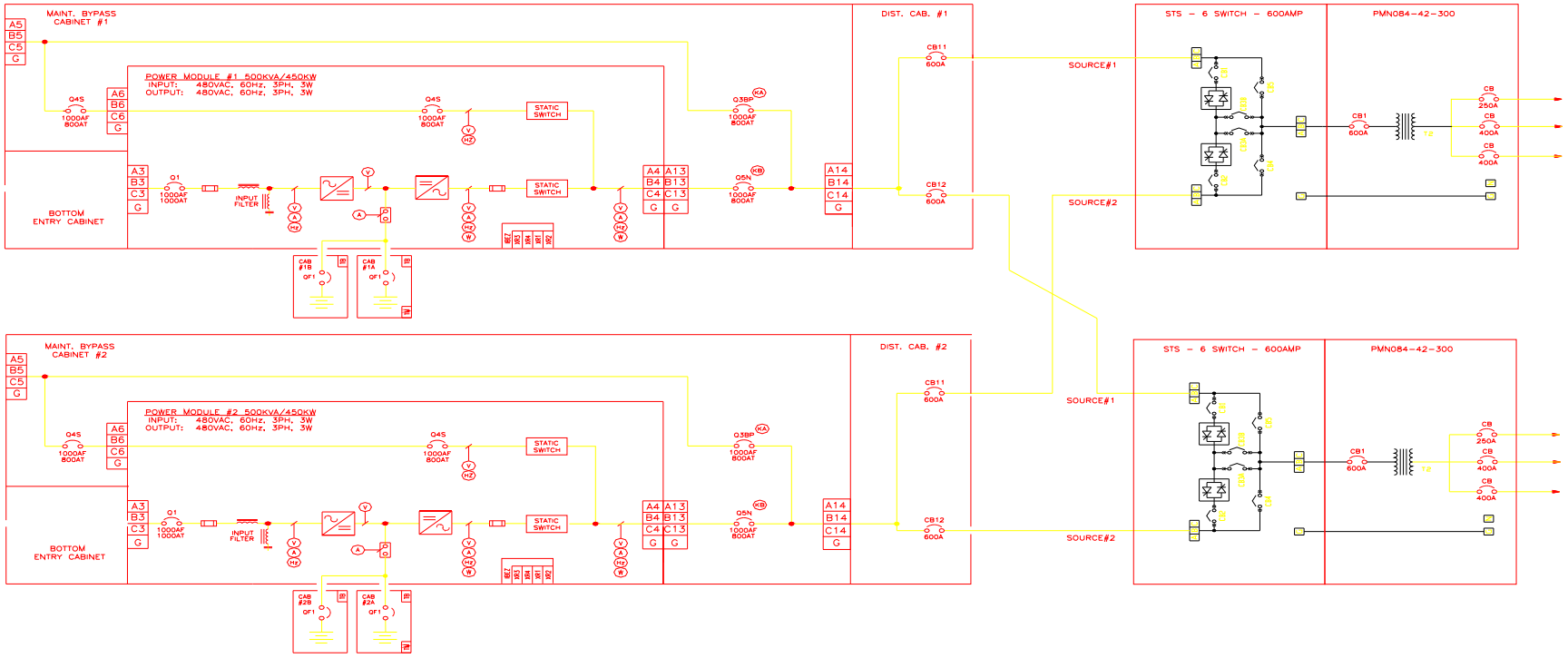
Efficiencies

Sections	1 1,075.26	2 1,053.9	3 1,050.3	4 1,038.9	5 1,022.7	6 1,004.2	7 1,000	Output 1,000 kW
Measured Losses, KW	22.17	2.79	11.4	16.2	18.5	4.2	-	75.26
Efficiency, %, by section	98.01	99.65	98.91	98.44	98.19	99.58	99.98	93.0 (summation)
Possible solution	Remove or change to auto	Remove	No change	No change	No change	Replace with mechanical device	Remove	
Impact	No isolation between input source and DC bus	ITHD = 8% (vs. 5%)	-	-	-	Increase overlap transfer time (from UPS to bypass)	-Install in system bypass cabinet	Increase to 94.5%

Total System losses

- System losses: Ave efficiency

UPS module = 94%, STS = 98.5%, PDU = 98.5%

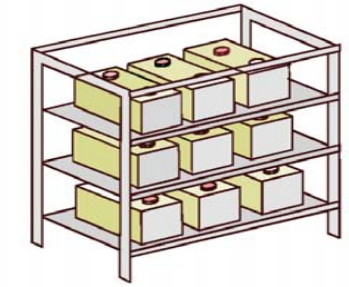


DC Power

- Wet Cell battery (includes 4-cell, 2-cell and 1-cell jars) manufacturer:
  - C&D - XTEnersys – DX
  - SG: 1.215 or 1.250
  - 2-tier or 3-tier racks

- Stackable (includes 4-cell, 3-cell, 2-cell and 1-cell jars):
  - Deka -
  - C&D
  - Enersys
  - GNB

- VRLA batteries (includes 6-cell jars):
  - C&D
  - Enersys (also have 16 volts battery)
  - GNB
  - Deka



DC Power

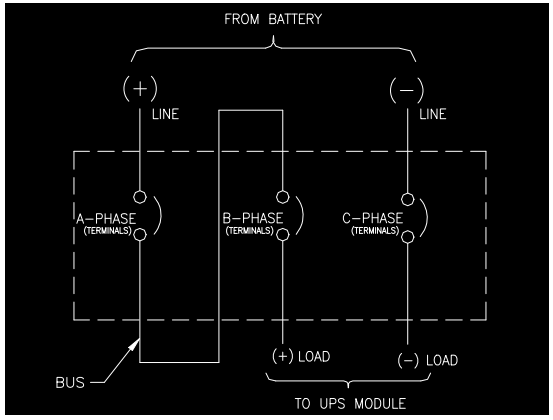
- Battery Parameters

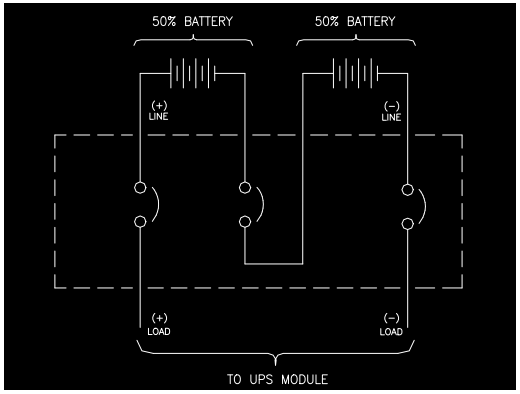
  - **Operating temperature**
    - Specified protection time @ 77° F (25° C)
    - Higher temperature > protection time
    - Lower temperature < protection time
  - **Discharges**
    - Number of discharges
    - Elevated cut-off voltage
    - Protection against deep discharge
  - **Battery charging**
    - Re-charge current
    - Temperature compensation
    - DC ripple: less than 1%

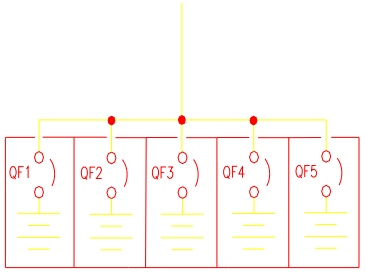
DC Power

- Single string (applies to wet cells battery or Stackable BRLA batteries
- High A-H ratings
- Longer run time
- Higher cost (purchase and installation)

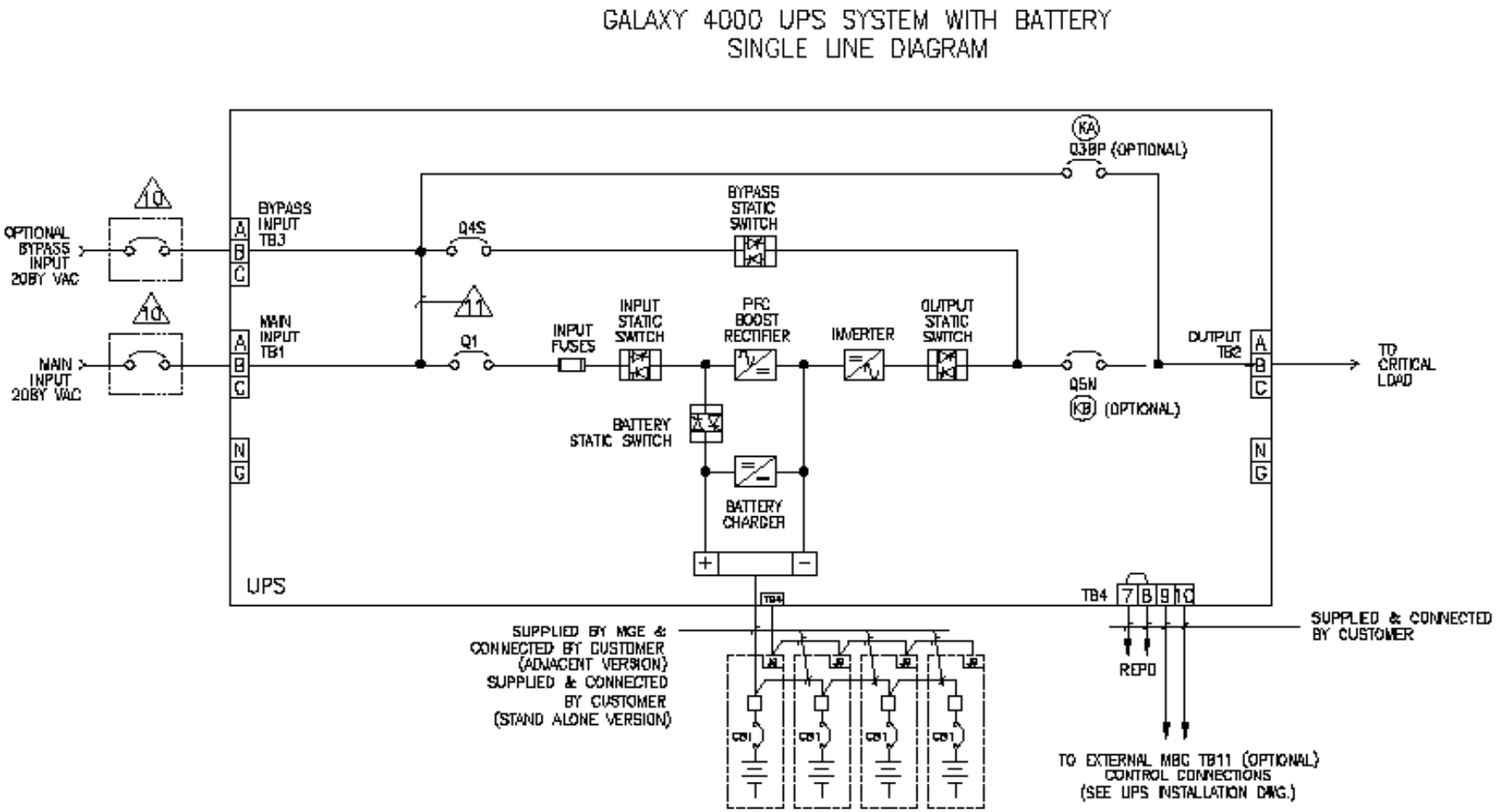
- Multiple strings -applies to VRLA batteries
- Limited A-H ratings
- Limited run time
- Cost effective



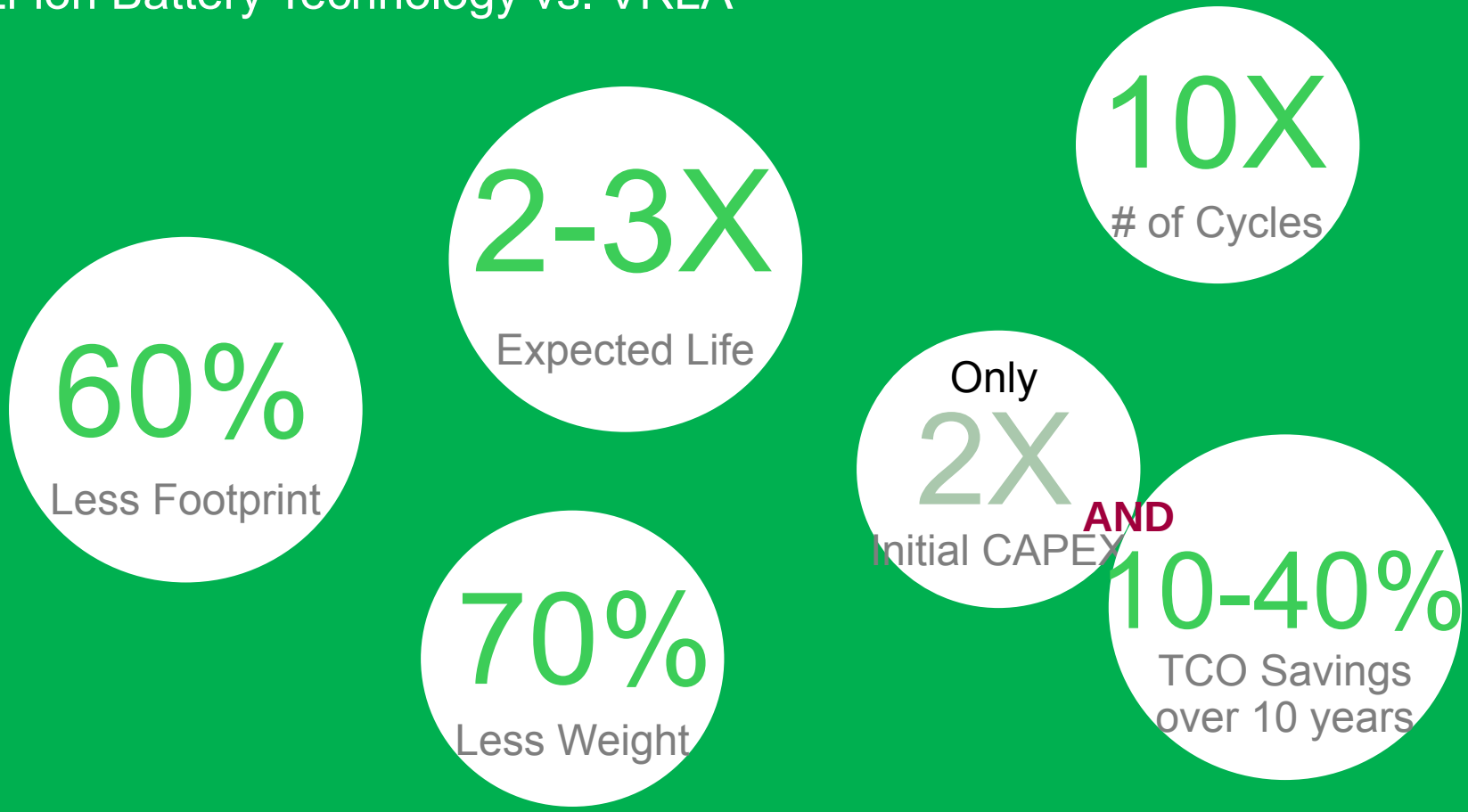




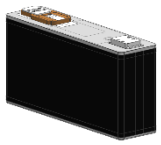
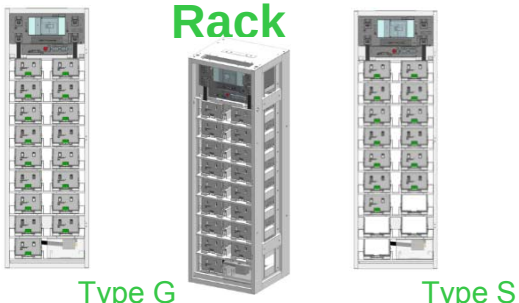
DC to DC converters



Li-ion Battery Technology vs. VRLA



System Component Specs.

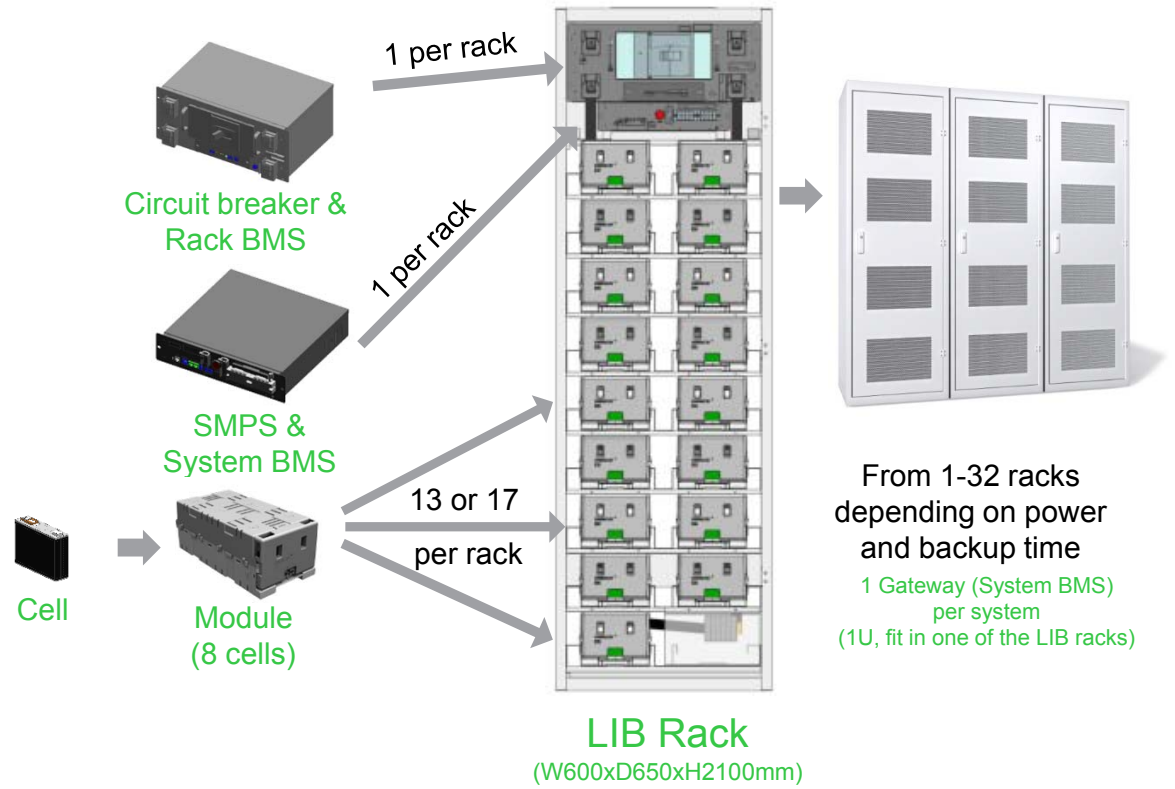
System Component	Cell	Module	Rack	
			 Type G	Type S
Configuration	1S1P	8S1P	136S1P	104S1P
Dimension (mm)	125.7x173.9x45.6	414x216x163	650Wx600Dx2055H	650Wx600Dx2055H
Weight (kg)	1.88 kg	17 kg	550 kg	480 kg
Nominal Voltage (V)	3.8V	30.4V	517V	395V
Nominal Current (A)	460 A			
Operating Range (V)	2.7V – 4.2V	24.0V – 33.6V	408V – 571V	312V – 437V
Capacity (Ah)	67 Ah			
Capacity (kWh)	0.254 kWh	2.04 kWh	34.6 kWh	26.5kWh
Nominal Power (kW)	1.7 kW	13.6 kW	231 kW	177 kW

LIB Solution

LIB Requirements for UPS application

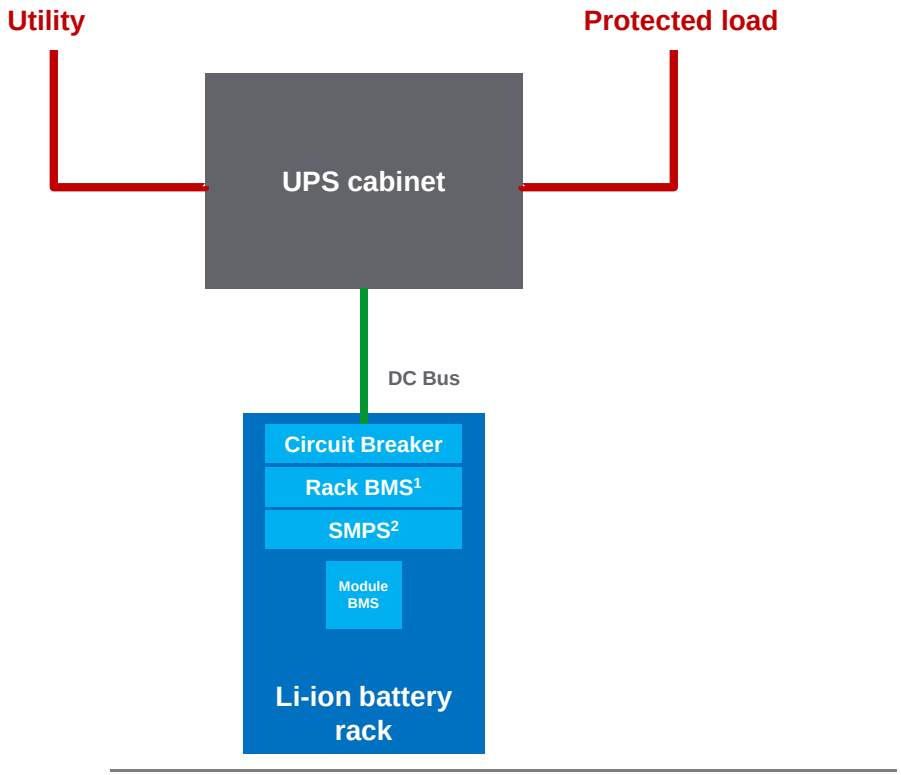
- Top safety technology
- High energy and power density: 35kWh and up to 230kW per rack
- Backup time from 5/6min to 30+min
- 15-years design life

A modular solution accommodating a wider range of needs



Solution design

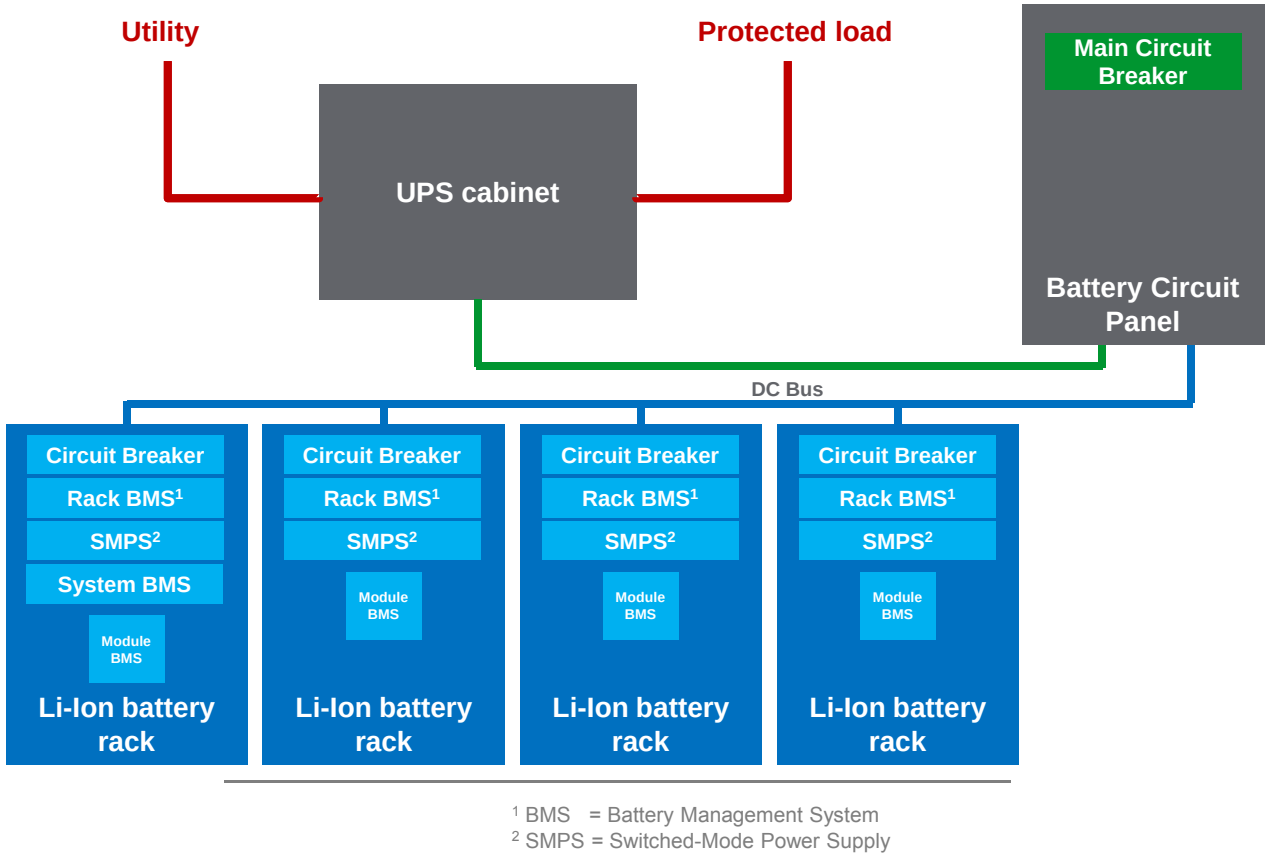
Single Battery Rack



[1] BMS = Battery Management System
[2] SMPS = Switched-Mode Power Supply

Solution design

Multiple Battery Racks



[1] BMS = Battery Management System
[2] SMPS = Switched-Mode Power Supply

Runtime Table

Rack Type	# of cells/rack	SE UPS	Power	1 rack	2 racks	3 racks	4 racks	5 racks	6 racks	7 racks	8 racks
G	136	G7K (PF=0.9)	300kVA	#N/A	13.0	20.5	27.5	35.0	42.5	49.5	57.0
G	136		400kVA	#N/A	9.5	15.0	20.5	26.0	31.5	37.0	42.5
G	136		500kVA	#N/A	#N/A	11.5	16.0	20.5	25.0	29.5	34.0
G	136	GVM	160kVA	12.5	27.0	41.0	55.0	69.0	83.0	97.0	110.0
G	136		180kVA	11.0	23.5	36.0	48.5	61.0	73.5	86.0	98.5
G	136		200kVA	10.0	21.0	32.5	43.5	55.0	66.0	77.5	88.5
G	136		225kVA	7.2	18.50	28.5	38.5	48.5	58.5	68.5	78.5
G	136	GVX	500kW	#N/A	#N/A	10.5	14.5	18.5	23.0	27.0	31.0
G	136		625kW	#N/A	#N/A	5.1	11.5	15.0	18.0	21.0	24.5
G	136		750kW	#N/A	#N/A	#N/A	9.50	12.0	14.5	17.5	20.0

Rack Type	# of cells/rack	SE UPS	Power	2 racks	4 racks	6 racks	8 racks	10 racks	12 racks	14 racks	16 racks
S	104	SyMW	400kW	#N/A	14.0	21.5	29.0	37.0	44.5	52.5	60.0
S	104		600kW	#N/A	8.2	14.0	19.0	24.0	29.0	34.5	39.5
S	104		800kW	#N/A	#N/A	10.0	14.0	17.5	21.5	25.5	29.0
S	104		1000kW	#N/A	#N/A	1.5	10.5	14.0	17.0	20.0	23.0
S	104		1200kW	#N/A	#N/A	#N/A	8.2	11.0	14.0	16.5	19.0
S	104		1400kW	#N/A	#N/A	#N/A	#N/A	9.6	11.5	14.0	16.0
S	104		1600kW	#N/A	#N/A	#N/A	#N/A	4.6	10.0	12.0	14.0

Runtimes are subject to tolerances (+/- 5%) and may vary

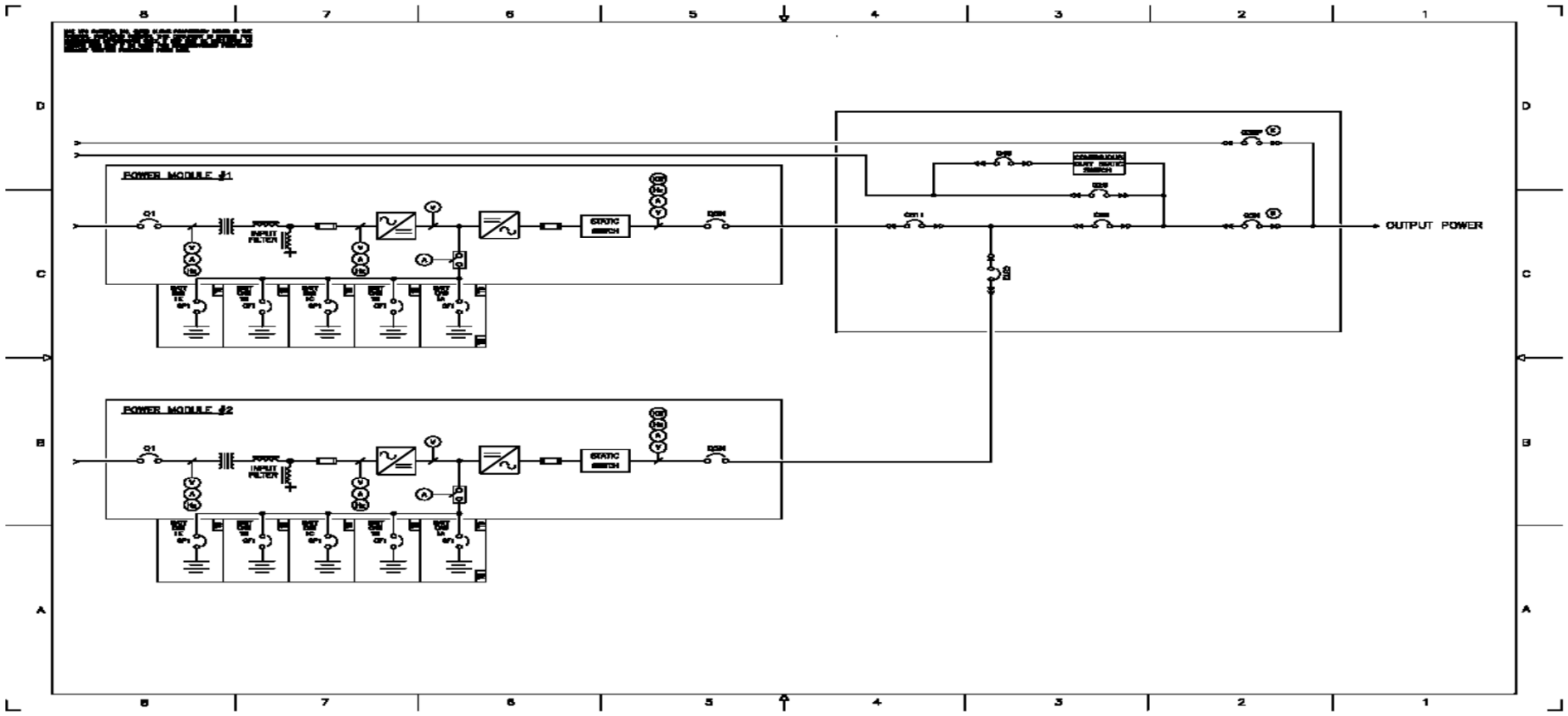
S* : Only half of rack type S is filled

Parallel Systems

	Centralized vs. IP		
	Centralized	**Integrated parallel**	**Comments**
Foot print	Requires System level Static switch, control cabinet, bypass CB and UOB (UPS inverters output breaker).	SBC (System Bypass Cabinet) about half the size.	IP configuration are in more demand. Every UPS vendor offers this configuration.
Cost	Reduction in price for static switch, bypass CB, and SSC cabinet. A slight increase in input switchgear if dual input per module is utilized (highly recommended).		Although considered "poor man" topology, the IP has benefits on cost and footprint
Operation	Standard parallel system	Standard parallel system	
	Transfer to & from bypass from centralized location	Transfer to & from bypass from centralized location	
	Transfer to bypass requires the firing on system level static switch.	Transfer to bypass requires the firing of all modules static switch	
	No concerns about current sharing while on bypass	While on bypass, paralleling static switches. Cable impedance is a major point for current sharing.	Cable run and cable management is very important point to consider during installation.
Fault current capabilities	Superior since the system level static switch (and bypass CB) are 100% rated for the full system ratings.	Very limited. Fault current does not share so the entire fault will flow through single module static switch.	Major point and very weak point for IP. No one wants to talk about this unless you want to sell centralized static switch.

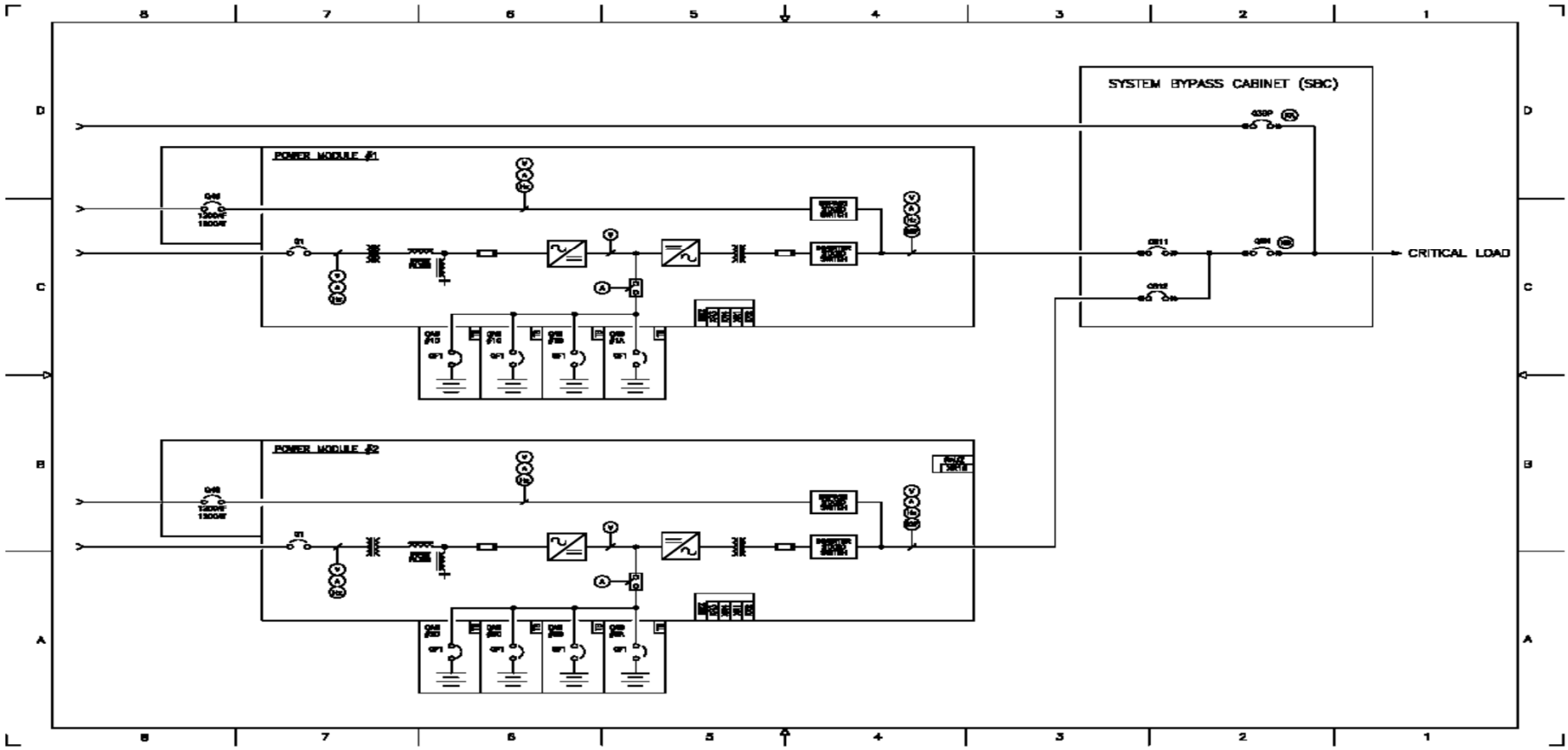
Centralized Static Switch Design

- UPS modules are based on parallel configuration
- Separate bypass cabinet that includes bypass CB, system level static switch, modules output isolation circuit breakers and maintenance bypass
- SSC is rated based on system ratings (capacity and/or redundancy)



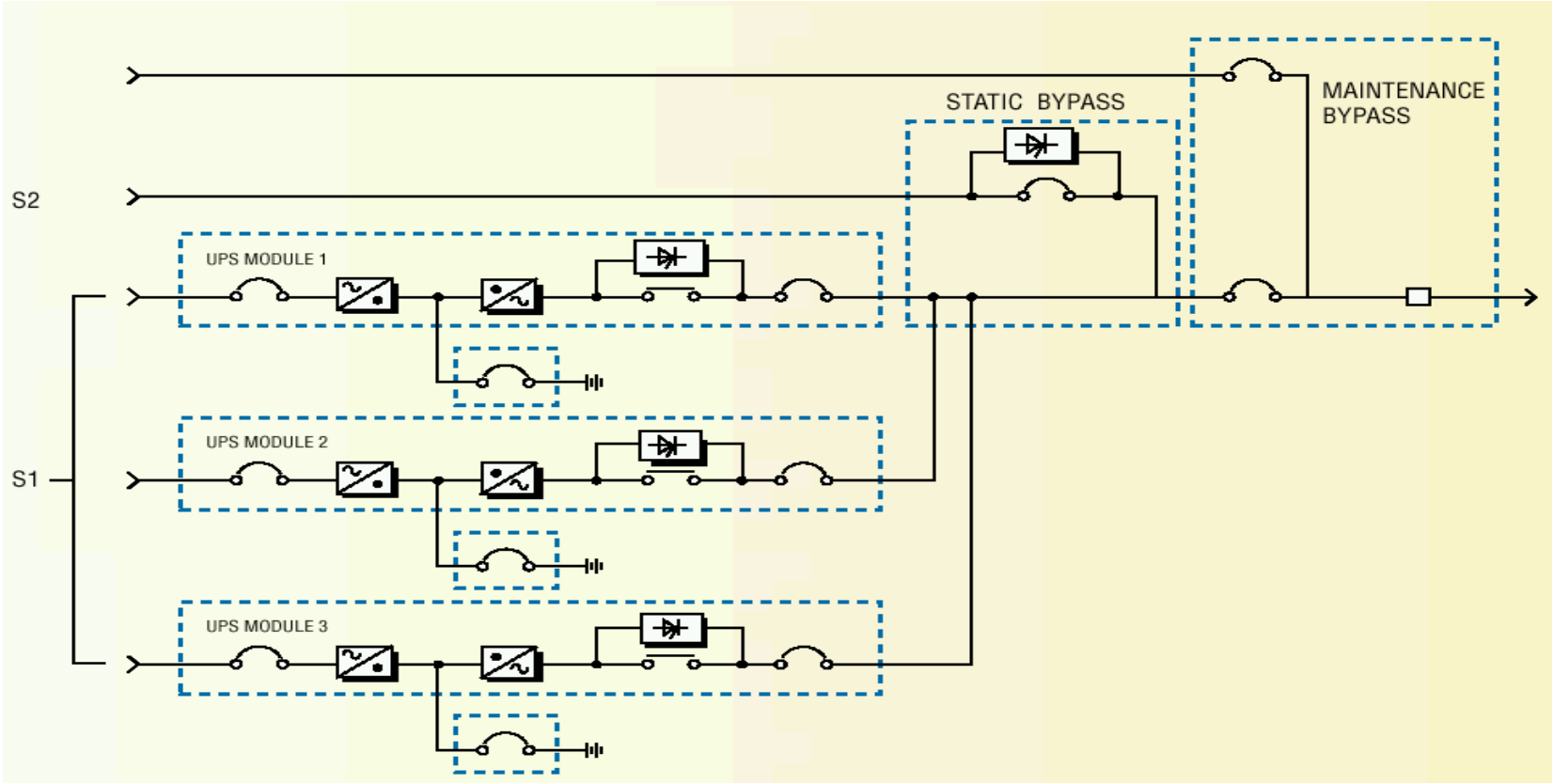
Integrated Parallel Design

- UPS modules are based on “single module” configuration
- Each UPS module has its own internal static bypass switch
- SBC is rated based on system ratings (capacity and/or redundancy)



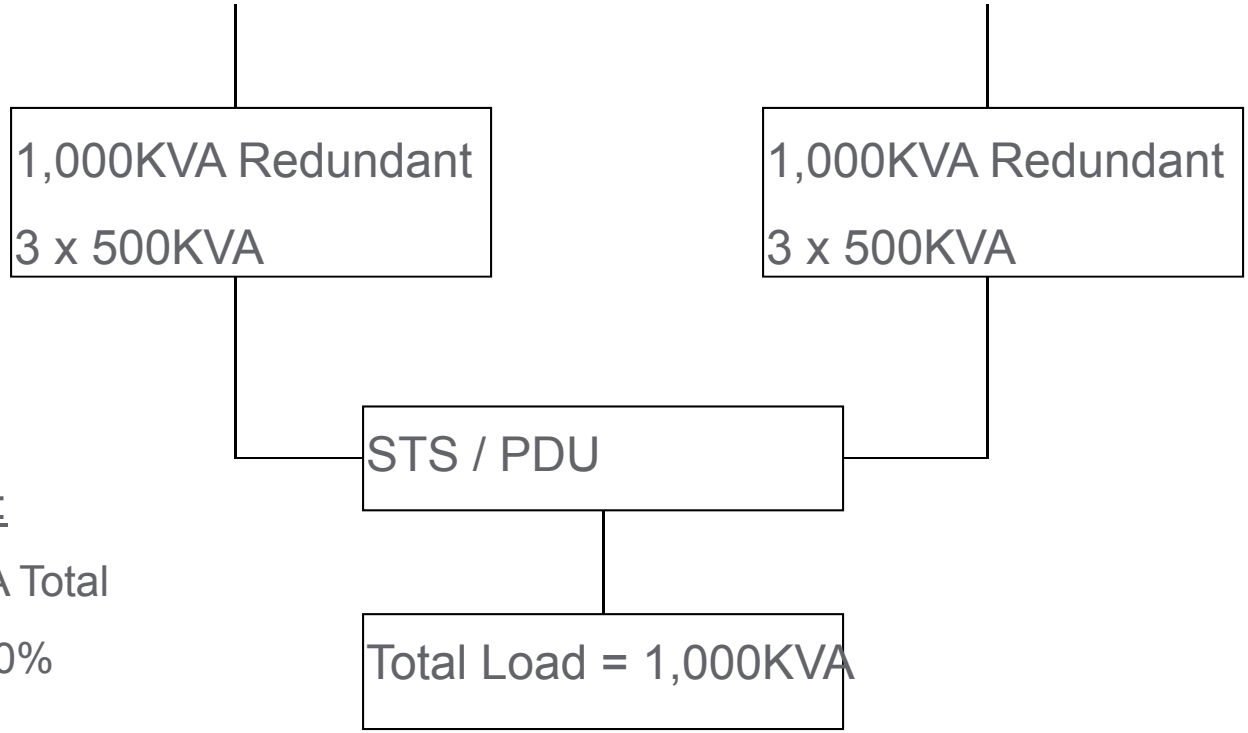
System Configuration

- Parallel for Capacity and/or Redundancy



System Configuration

- Parallel for Capacity and/or Redundancy 2 (N+1)



Load Calculation:

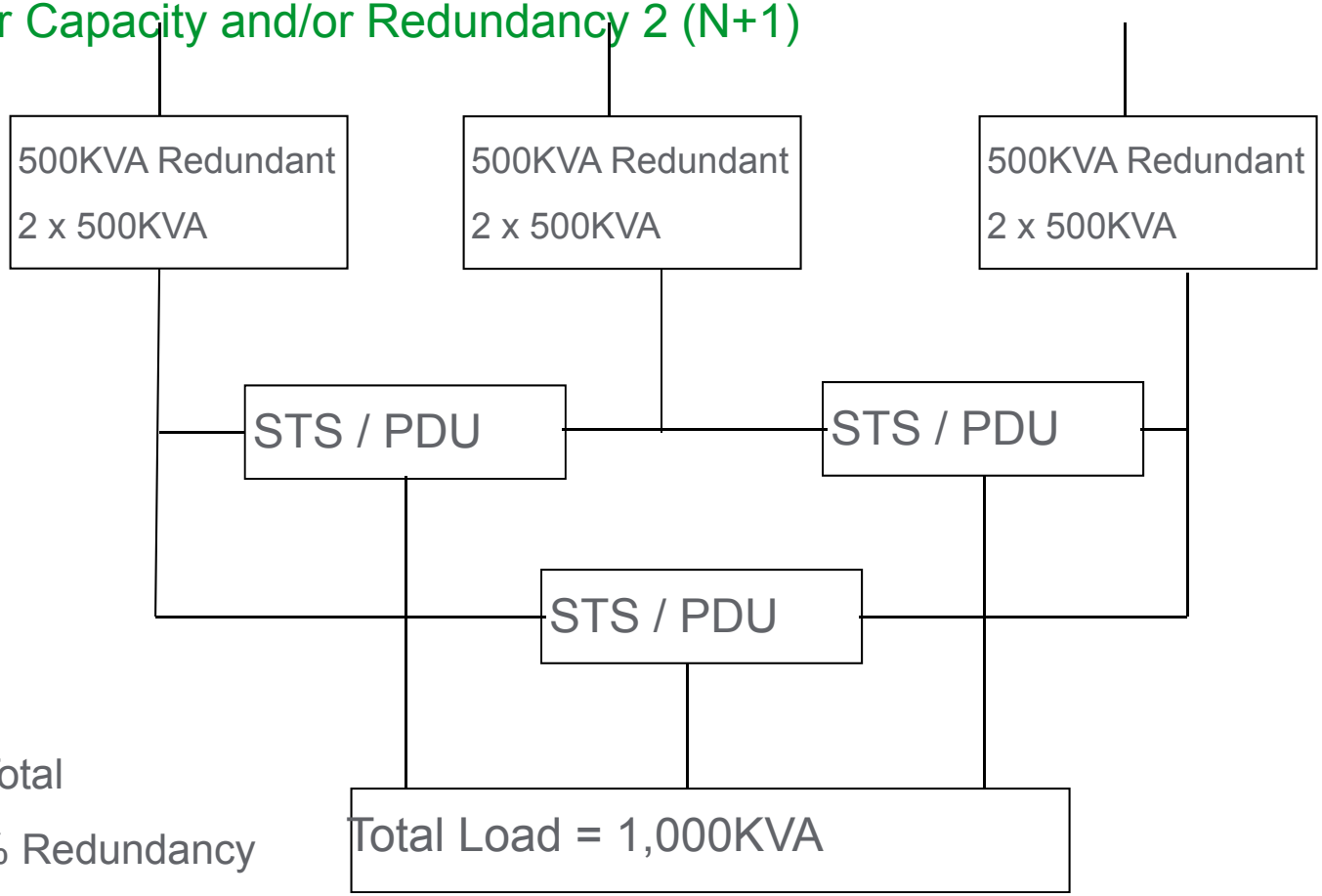
Load = 1,000KVA Total

UPS System = 50% Redundancy

Each System supports 500KVA

System Configuration

- Parallel for Capacity and/or Redundancy 2 (N+1)



Load Calculation:

Load = 1,000KVA Total

UPS System = 66% Redundancy

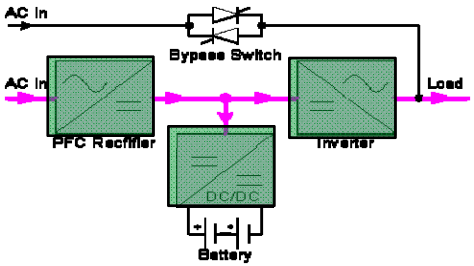
Each System supports 333KVA

EConversion

The best of double conversion and Eco mode

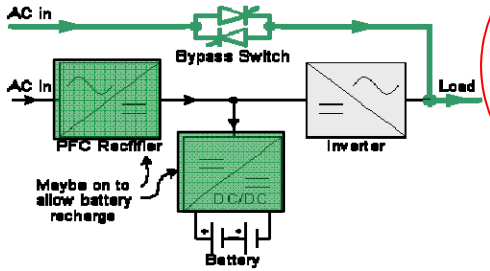
Electrical

Double conversion



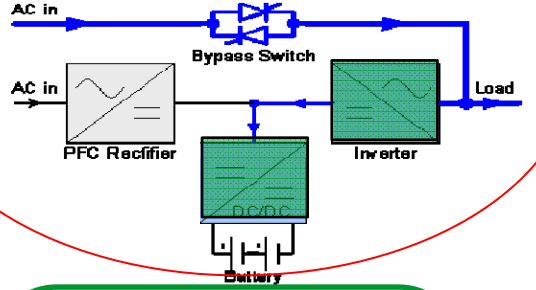
Regulate Voltage	✓
Regulate frequency	✓
Recharge batteries	✓
Load PFC	✓
No time transfer	✓
Efficiency : 96+%	✓ ✗

Usual ECO mode



Regulate Voltage	✗
Regulate frequency	✗
Recharge batteries	✓
Load PFC	✗
No time transfer	✗
Efficiency : 99 %	✓

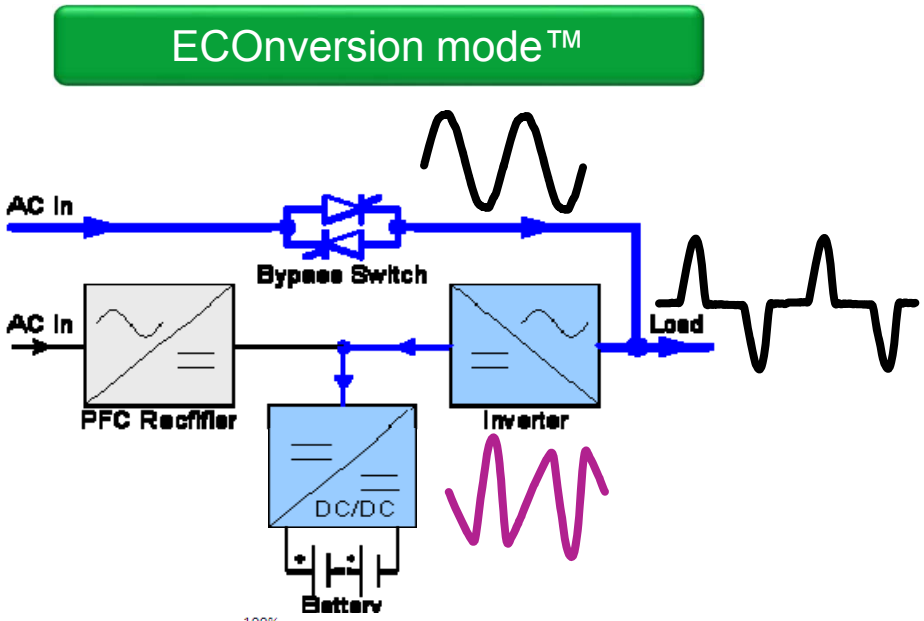
ECOnversion mode™

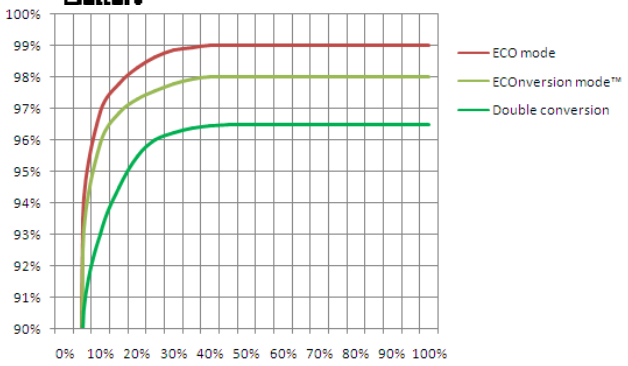


Regulate Voltage	✗
Regulate frequency	✗
Recharge batteries	✓
Load PFC	✓
No time transfer	✓
Efficiency : 98,5 %	✓

ECOnversion Mode

How does it Work?





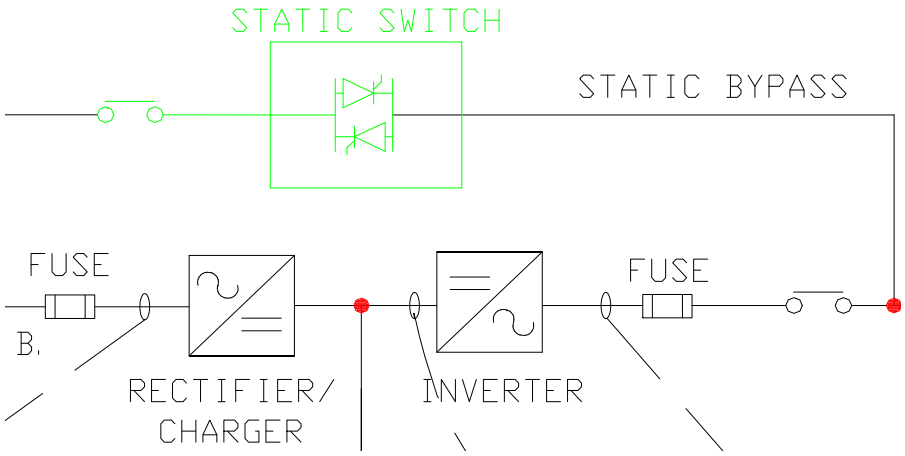
ə

ECOnversion Mode

- Primary power path is through static bypass switch
- Inverter is ON, synchronized and parallel with static switch
- Bi-directional Inverter is charging the DC Bus, batteries charge
- Inverter acts as PFC
  - Corrects power factor
  - Filters harmonics
- If power to bypass is interrupted, Inverter seamlessly powers load (no break in output power)
- Bypass Switch SCRs can be controlled like ‘diodes’
  - Upstream faults can be mitigated by allowing current in one direction only (current flow to load)

Static Bypass Components

- Backfeed protective device
  - Required by UL
- Static Switch
  - provides “uninterrupted transfer” between utility and inverter
  - provides voltage reference for inverter
  - Types
    - **momentary**
    - **continuous**

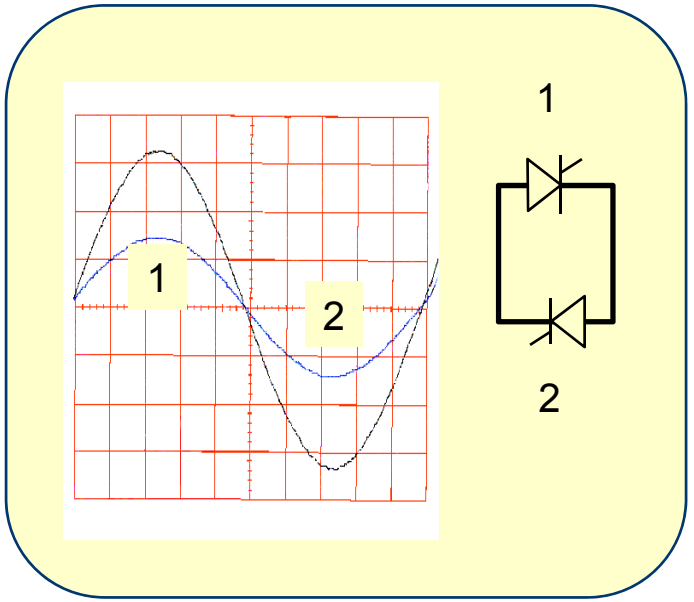


Static Switch

- Main Static switch consists of anti-parallel connected SCR

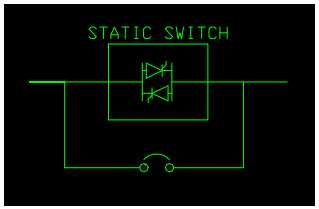
SCR 1 is conducting the current for the “positive” half cycle. The SCR cannot conduct current in the opposite direction - it works as a diode.

SCR 1 is conducting the current for the “negative” half cycle. The SCR cannot conduct current in the opposite direction - it works as a diode.



Static Switch Design

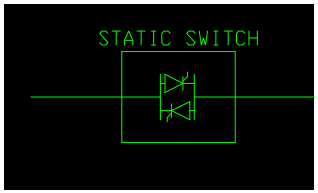
100% rated for Momentary duty



Advantages:
•Less expensive
•Smaller footprint

Disadvantages
•Less Reliability

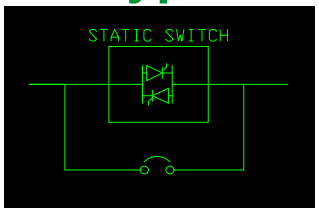
100% rated for Continuous duty



Advantages:
•Higher Reliability
•Better performance
• Standard Feature for Schneider

Disadvantages
•More expensive
•Larger footprint

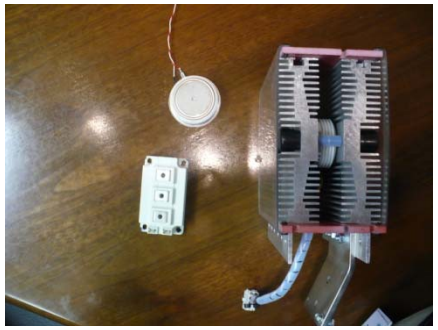
100% rated for continuous duty with bypass CB

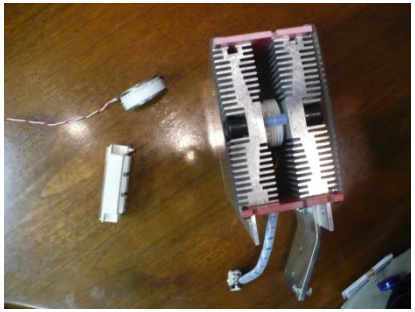


Advantages:
•Much Higher Reliability (redundant bypass)
•Better performance
• Typical for parallel system with centralized static switch

Disadvantages
•Much more expensive
•Larger footprint

Static Switch Semiconductors

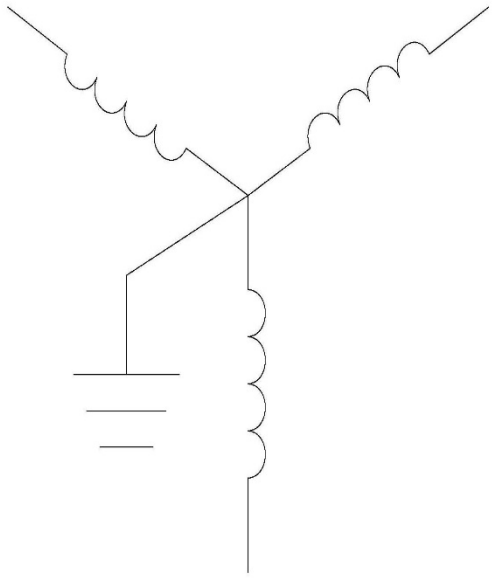




	Static Switch Semiconductors		
	Brick Type	**Hockey Puck**	**Comments**
Cost	1. Less expensive device 2. Less expensive to manufacture 3. Easy to assemble	1. More expensive device 2. More expensive to manufacture the assembly 3. Harder to assemble (very specific torque requirements and assembly procedure)	
Operation	Same switching speed	Same gating and firing controls	Same efficiency
Fault capabilities	1. Harder to cool (single sided heat sink) 2. Much higher chances to rupture under fault condition. 3. Fails in open circuit position	1. Heat sink assembly is structured by sandwiching the SCR between two layers of heat sink switch clamped down with high pressure. 2. Almost impossible to rupture under fault condition. 3. Fails in short circuit position	Hockey puck SCR are widely used in high-high power application. The construction of the assembly creates rugged structure that can sustain high surge current, and it also provides excellent cooling that makes it suitable for higher current applications.

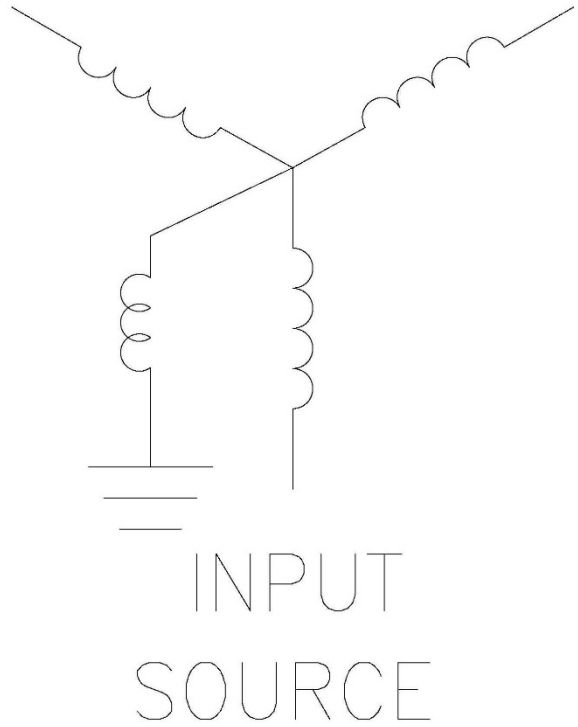
Grounded Input Source

- Input Power source is grounded. The mid-point (neutral) is reference to ground.
- This is applicable to 480 or 600 Volts system.
- This is also applies t0 208 and 400 volts system.



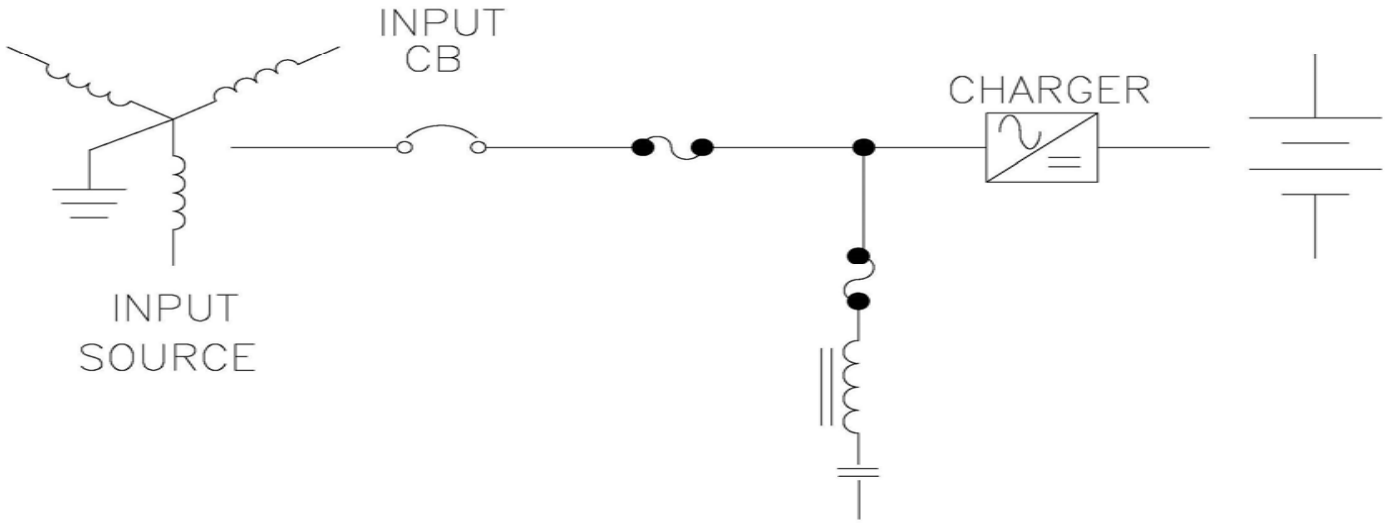
HRG – High Resistance Grounded Source

- The Input Source is Grounded through a resistor (current limiting device)
- This is applicable to 480 and 600 volts system only.
- The resistor value is determined based on the ground current fault (typically it is set between 10 to 50 amps).
- The system is provided with current and voltage monitoring for indication.
- Under normal operation the current is zero.



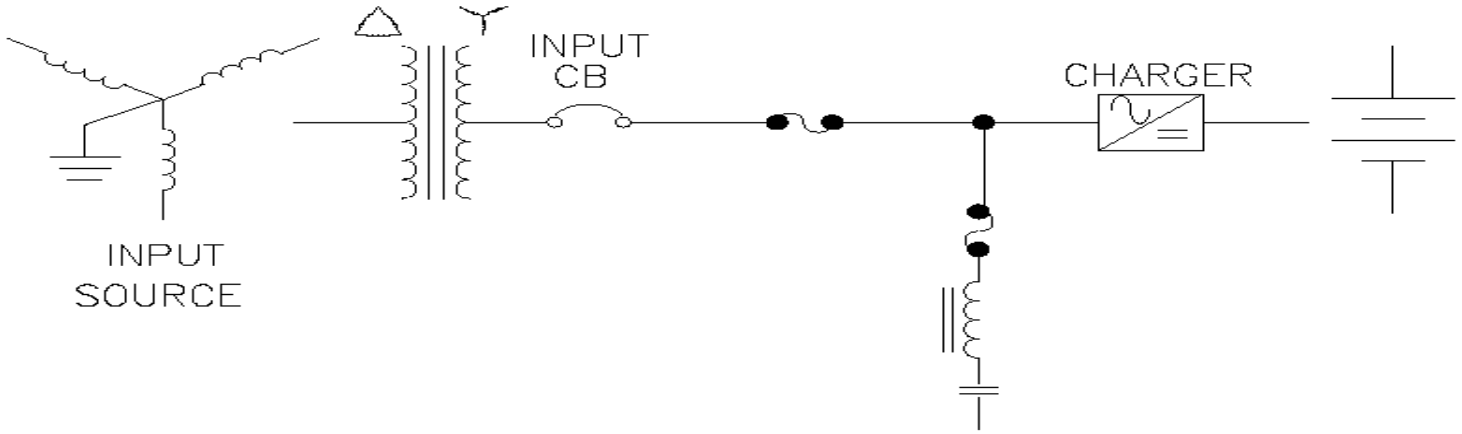
Rectifier/Charger with Grounded input Source

- Input source is grounded.
- No galvanic isolation between the Input source and the DC bus (the battery).
- Battery mid-point is reference to zero (50% voltage from zero to + and 50% from zero to -).
- Ground fault on the DC bus will cause fault and shut down.



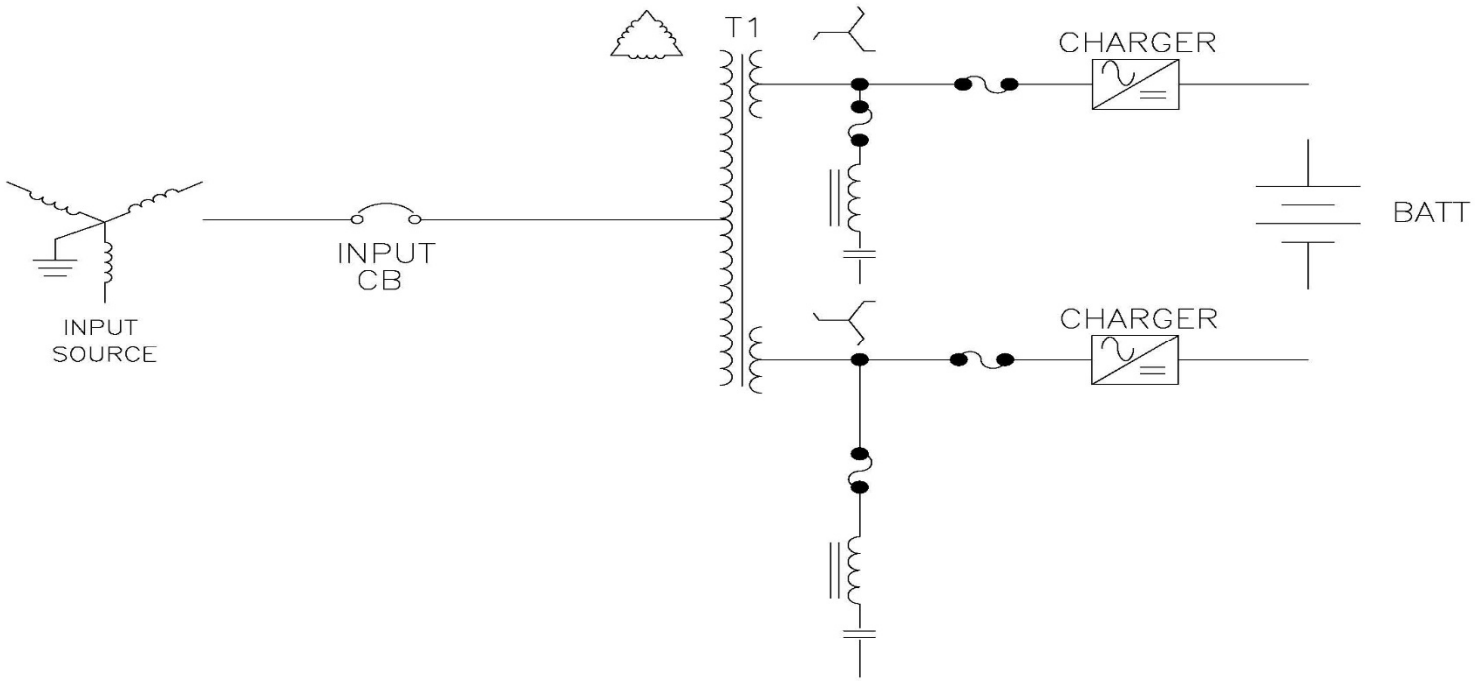
Rectifier/Charger with input Isolation Transformer

- Input source is grounded.
- UPS Input isolation transformer provides galvanic isolation between the source and the DC bus (the battery).
- Battery system is floating – no reference to ground.
- Ground fault on the DC bus will cause an alarm but NOT a shut down.



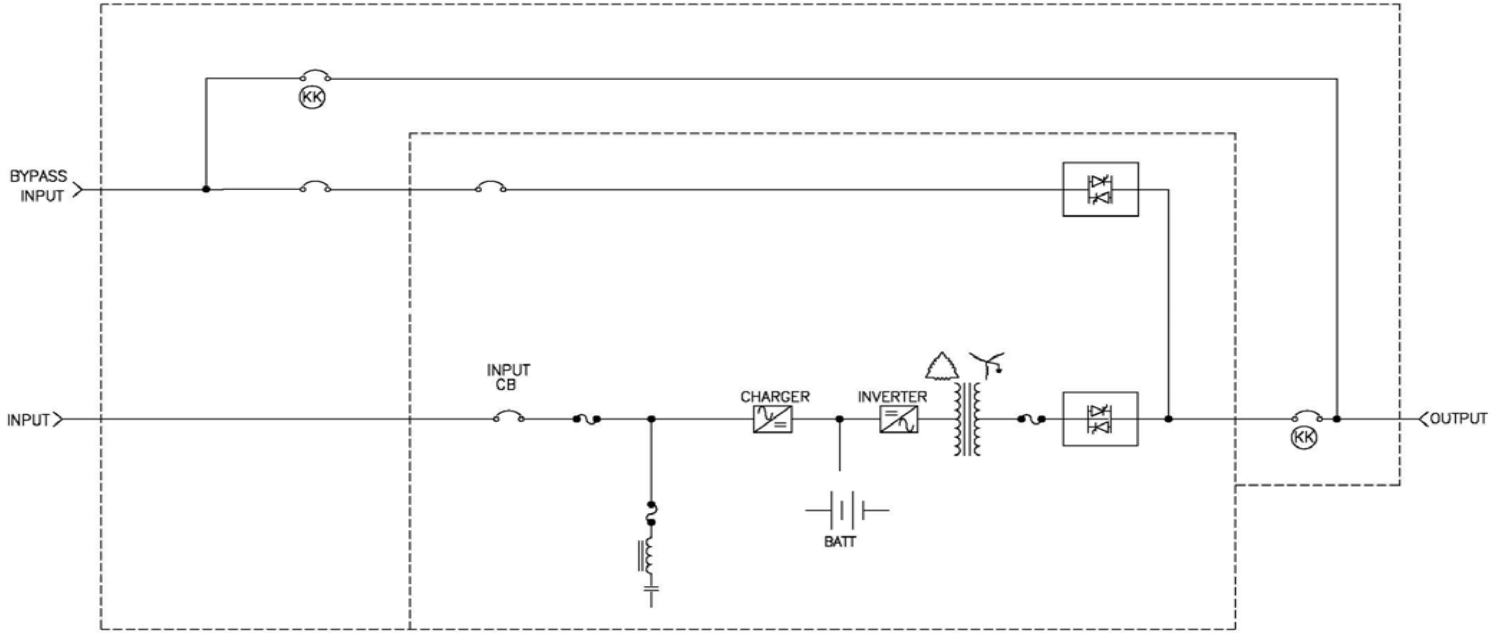
12-pulse Rectifier/Charger

- Input source is grounded.
- UPS Input isolation transformer provides galvanic isolation between the source and the DC bus (the battery).
- Battery system is floating – no reference to ground.
- Ground fault on the DC bus will cause an alarm but NOT a shut down.



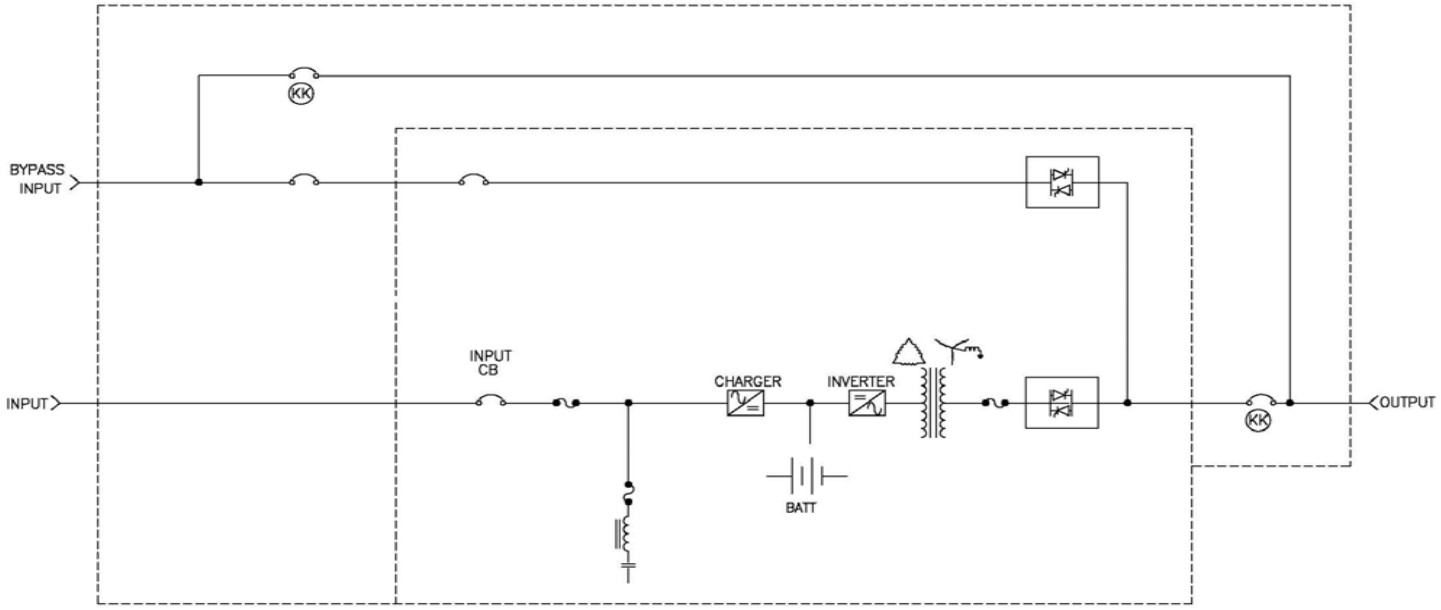
Single module with Grounded Output

- UPS Inverter output neutral is grounded
- AC ground fault on the load will cause UPS shut down (short circuit condition).



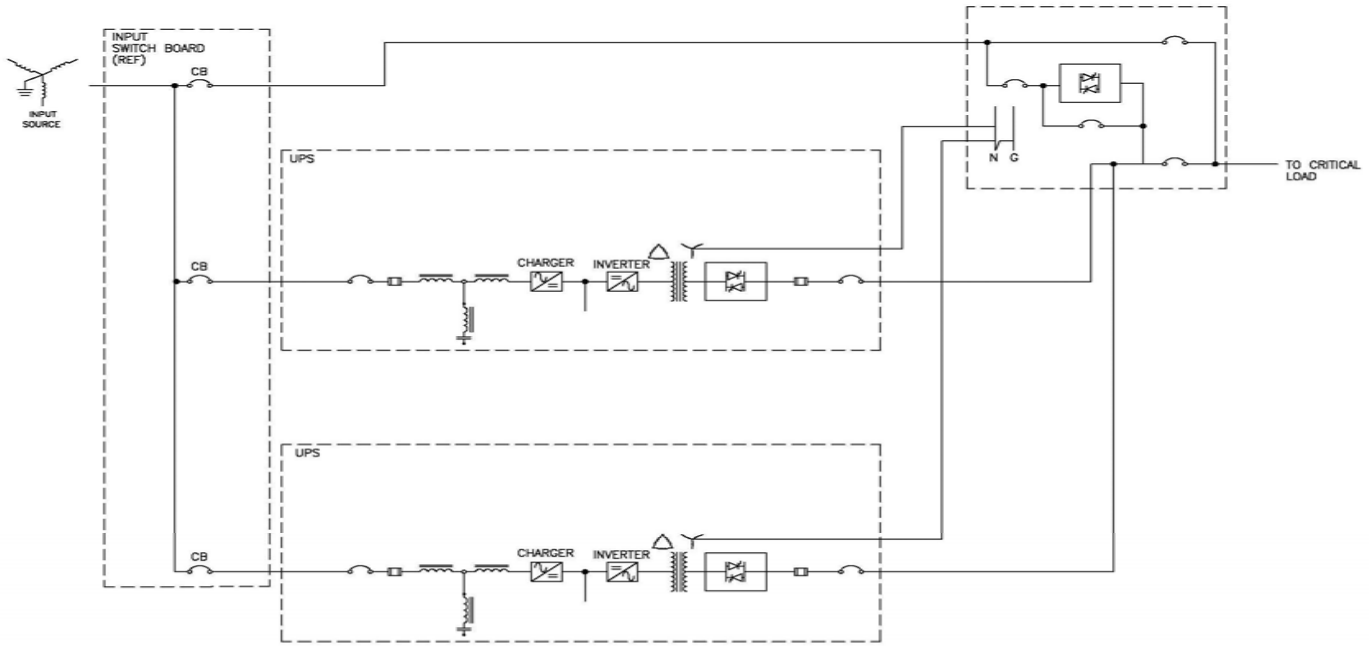
Single Module with HRG output

- UPS Inverter output neutral is HRG
- AC ground fault on the load will cause an alarm but the UPS module will continue to function and support the load (no shut down).



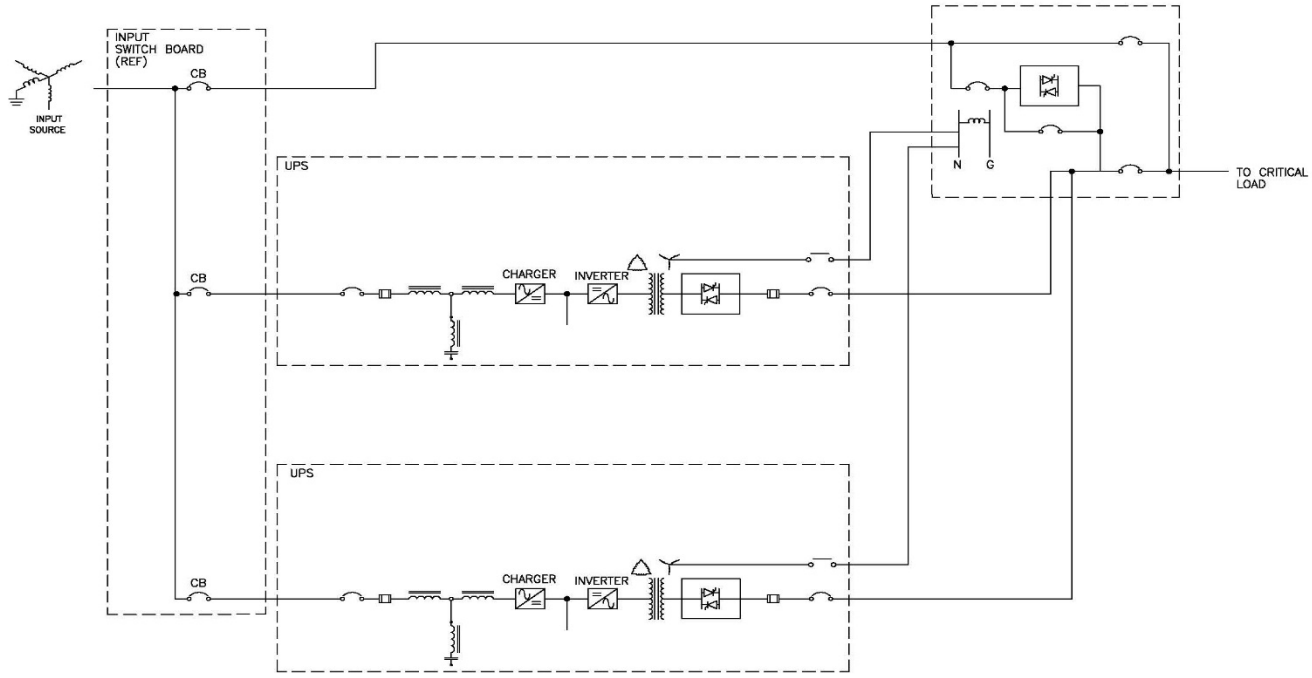
Parallel System
with Grounded Source & UPS Output

- UPS Inverter output neutral are connected together in the system bypass cabinet
- The neutral is grounded in the system bypass cabinet.
- AC ground fault on the load will cause UPS module shut down (short circuit condition).



Parallel System
with HRG Source & HRG UPS Output

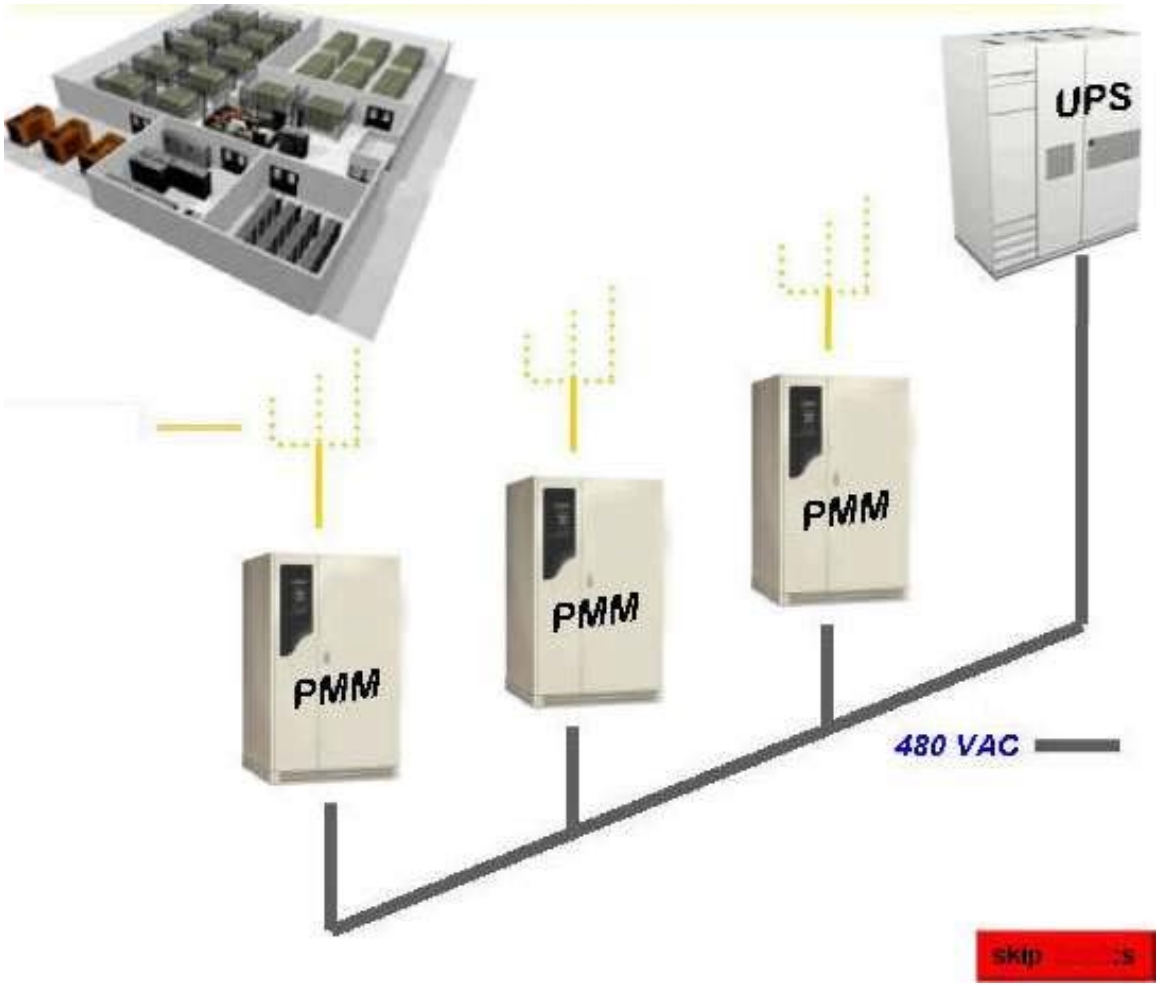
- UPS Inverter output neutral are connected together in the system bypass cabinet
- The neutral is HRG in the system bypass cabinet.
- Each UPS module output Neutral is isolated through contactor.
- AC ground fault on the load will cause UPS module shut down (short circuit condition).



Market Requirements

- Voltage requirements (for 60 Hz and 3-phase application):
  - 208, 400/415, 480 and 575/600 Volts
- System configuration:
  - Single module
  - Isolated redundant
  - Parallel for capacity and/or redundancy with centralized/system level static switch
  - Parallel for capacity and/or redundancy in Integrated Parallel
- System application:
  - 3-Phase, 3-wire
  - 3-Phase, 4-wire
  - HRG (High Resistance Ground) – Input source (utility and/or generator) and/or output.
  - Flywheel application

Power Distribution Basics



480
Or
575/600 VAC

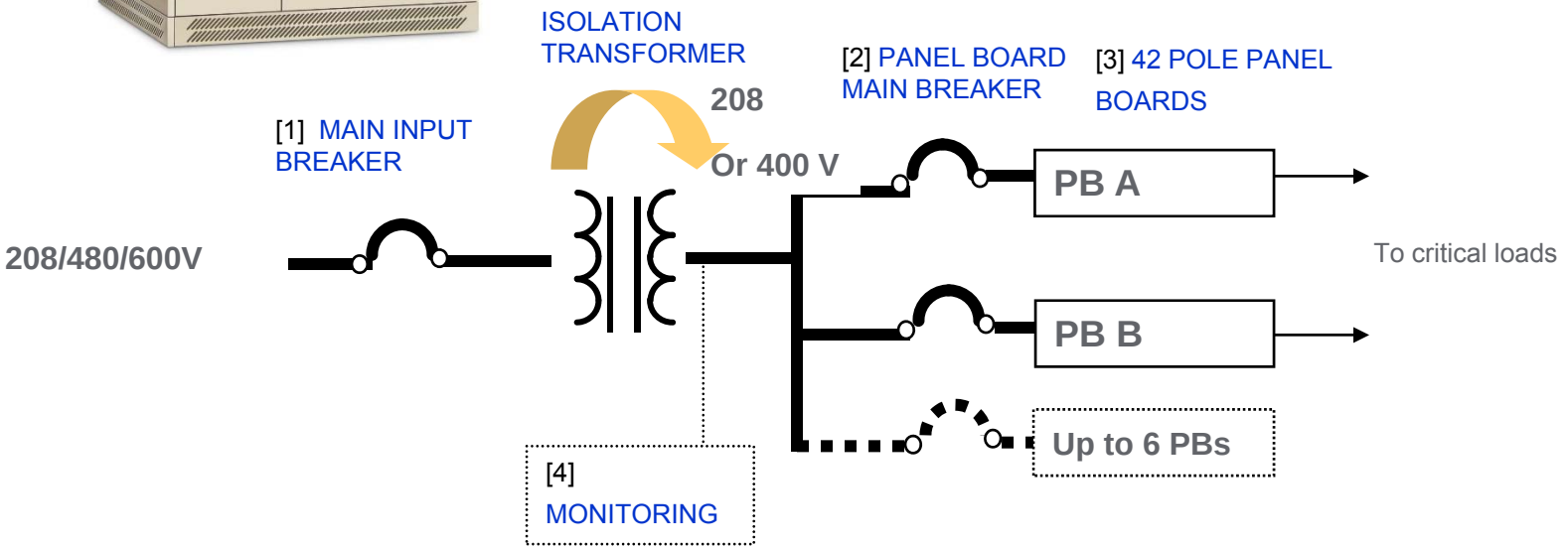
208/120
Or
400/230 VAC

PDU STANDARD FEATURES

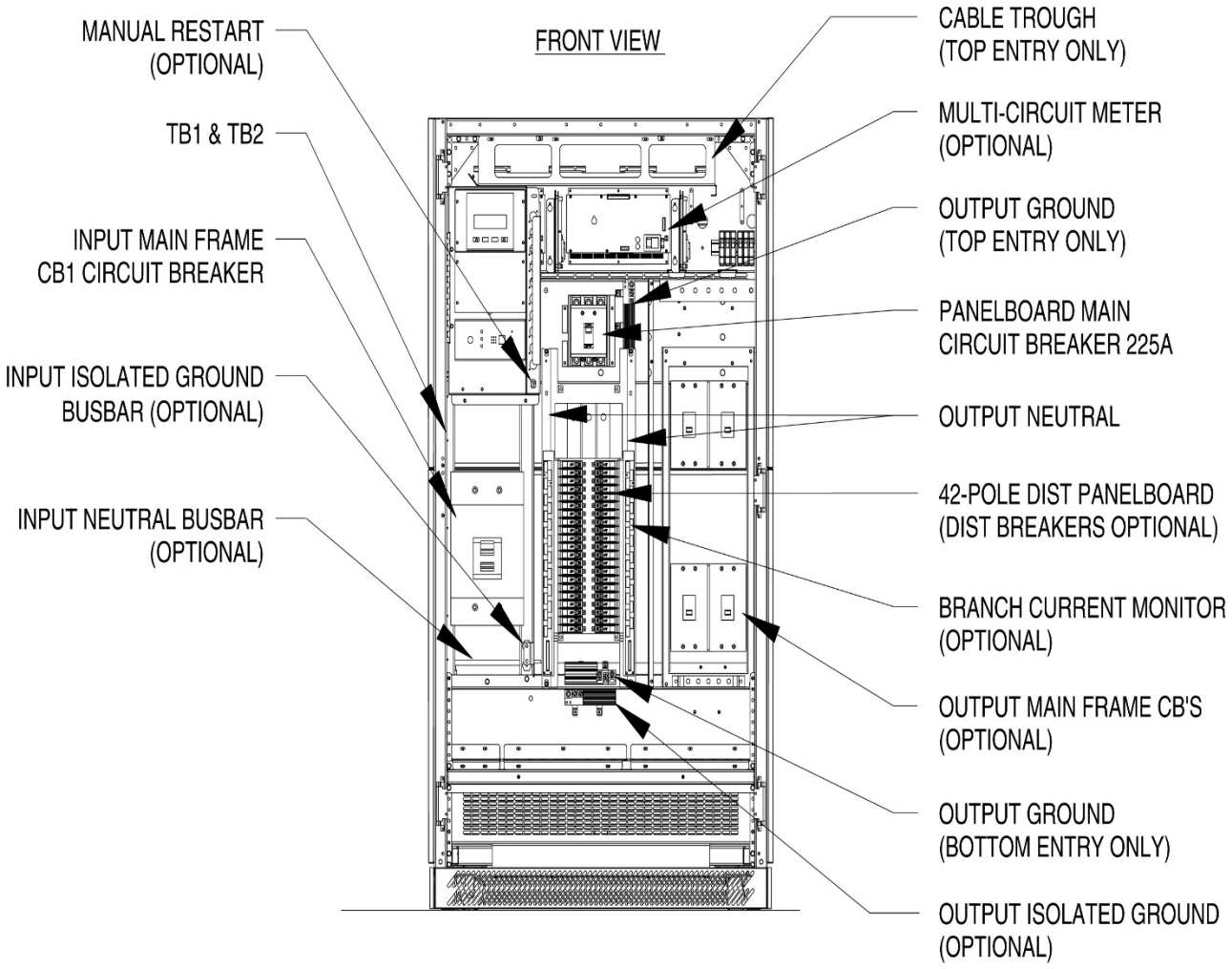
- 30 kVA – 300 kVA (and 500 kVA)
- 208/480/600V input
- 208/120V or *400/230 V output*
- Two (2) or up to 6 x 42 pole panelboards with main breakers.
- K rated isolation transformer
- 200% rated neutral bus
- Local EPO
- Front facing
- Front access
- Bottom or top cable entry

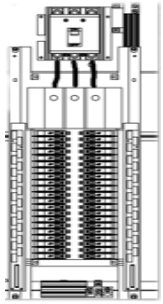
PMM TOPOLOGY

- Main Input Breaker
- Isolation Transformer (in rear of cabinet / not shown)
- Panelboard Main Circuit Breaker (on each panelboard)
- Panelboards (each accommodates 42 circuit breakers)
- Monitor/Meter (monitors system performance - optional)



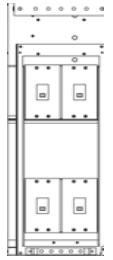
PMM TOPOLOGY





42 POLE PANELBOARD

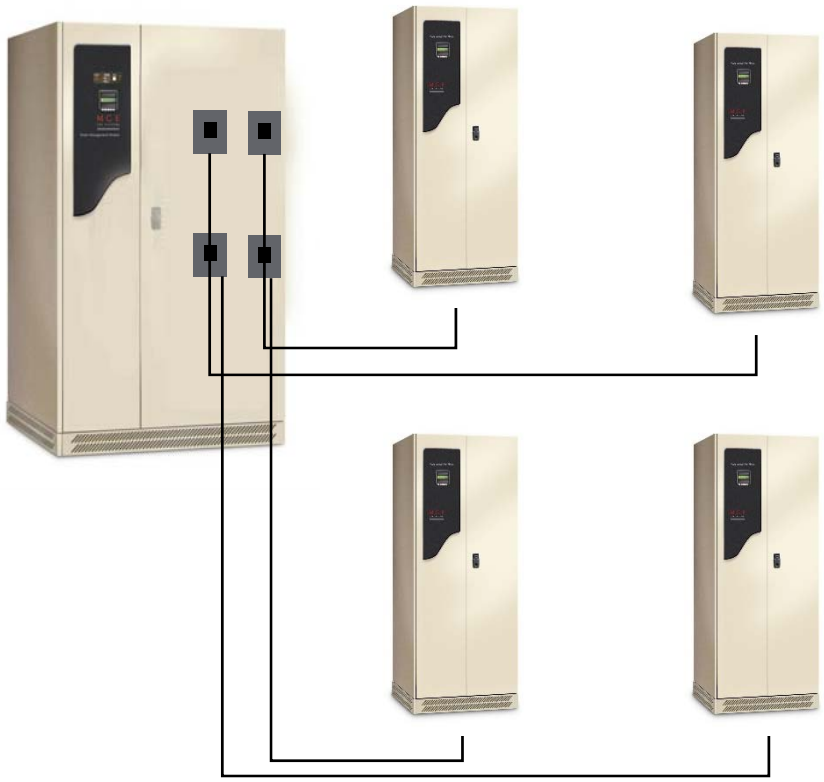
w/MAIN BREAKER



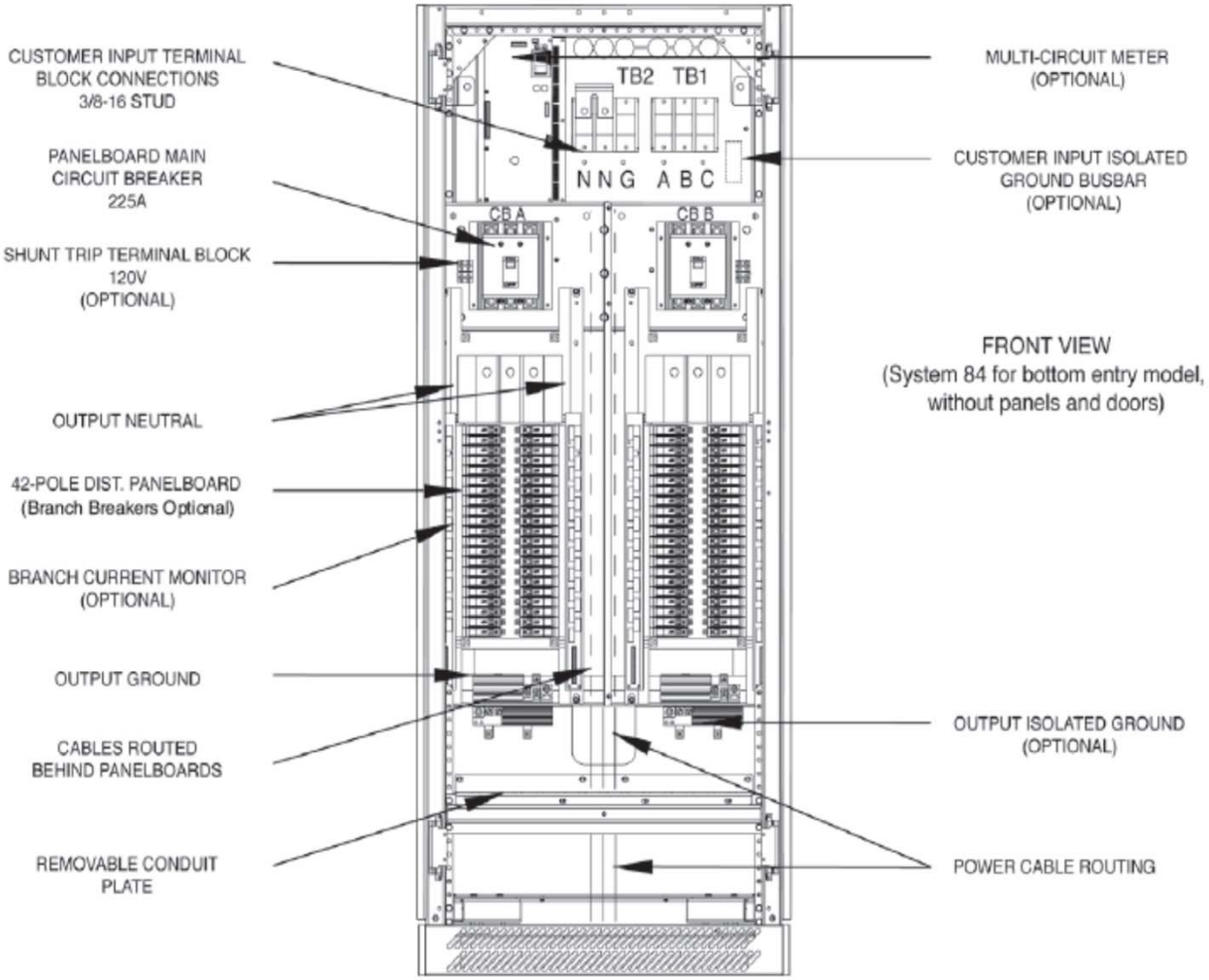
4 x 225A DISTRIBUTION BREAKERS

REMOTE Power Panels (RPP)

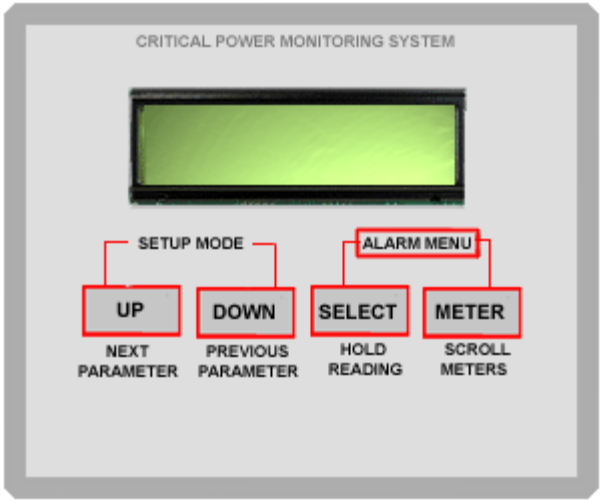
- 208 or 400 V 3-phase, 4-wire input
- 208/120V or 400/230 V output
- 2 or 4 x 42 pole panelboards
- Panelboard main circuit breaker
- Fed via distribution breakers on the PDU.
- Bottom or top cable entry

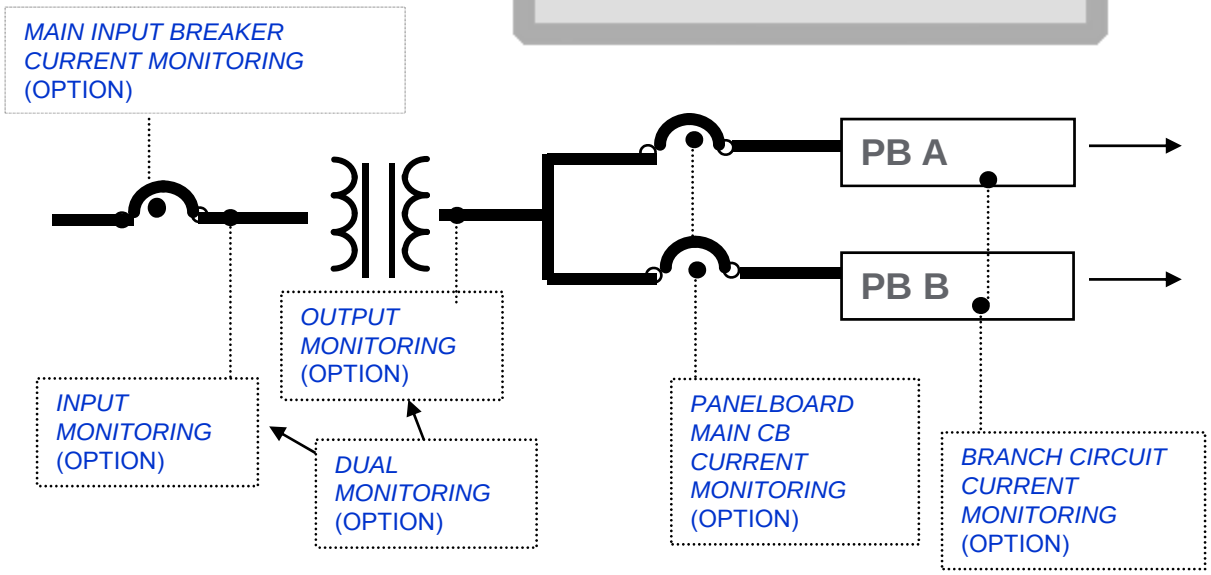


RPP TOPOLOGY



PDU MONITORING





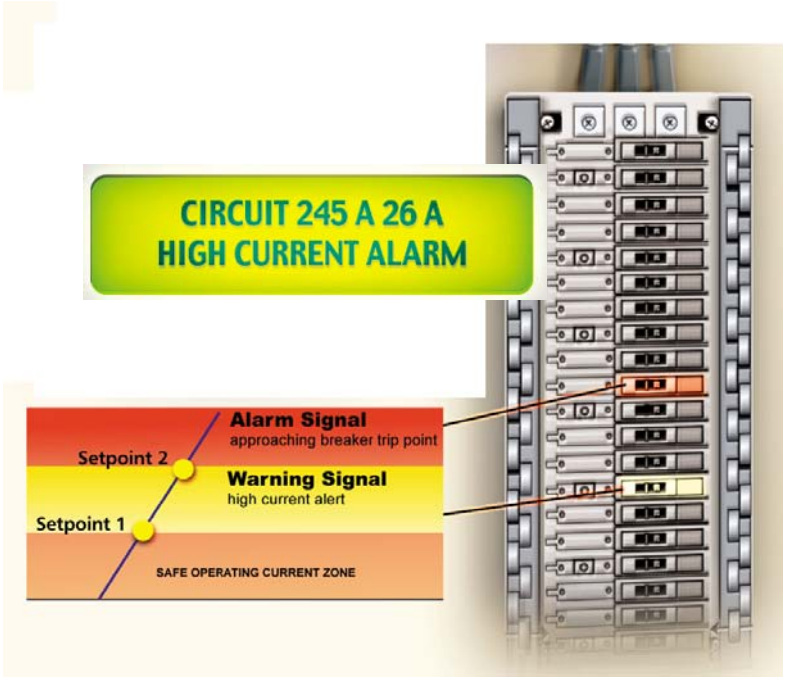
Features:

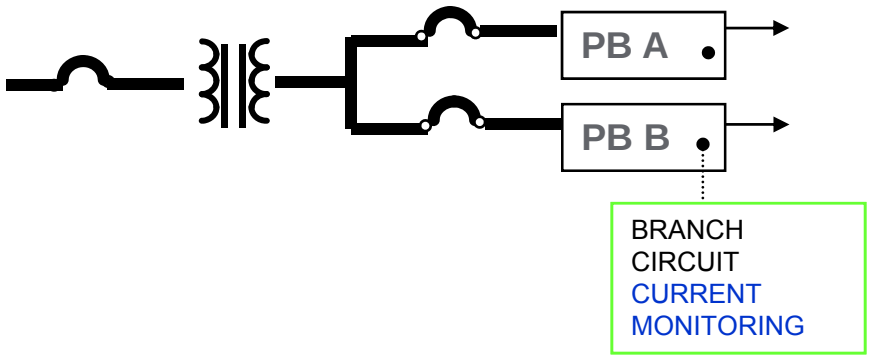
- ã Monitors input and/or output
- ã Dry contact alarm output
- ã Alarm log
- ã IR port for downloading to Palm Pilot
- ã RS485 serial output
- ã True rms metering
- ã Nonvolatile Memory
- ã Min/Max reading of values for real time readings
- ã Set-Point controlled alarm & relay functions
- ã Modbus Protocol
- ã Password protected

Options:

- ã Main input breaker current monitoring
- ã Panelboard main breaker current monitoring
- ã Branch circuit current monitoring
- ã Mainframe breaker current monitoring
- ã Web enabled (EGX option)

BRANCH CIRCUIT CURRENT MONITORING

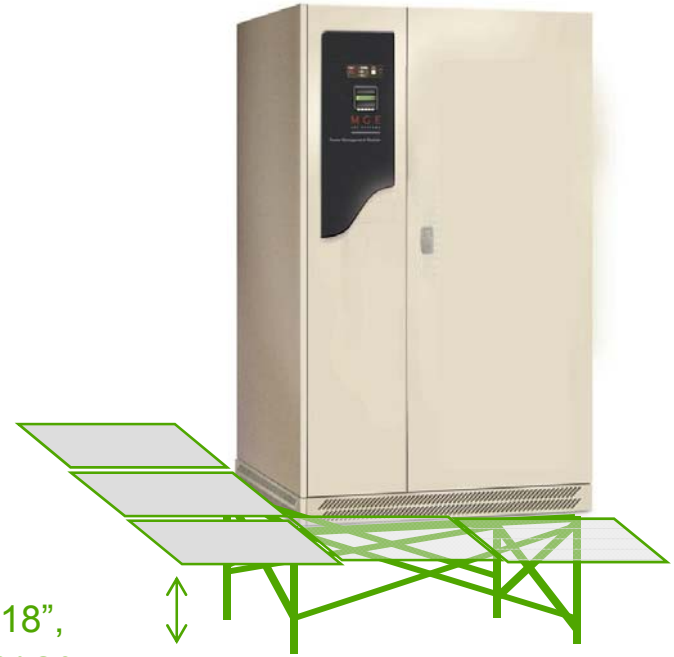




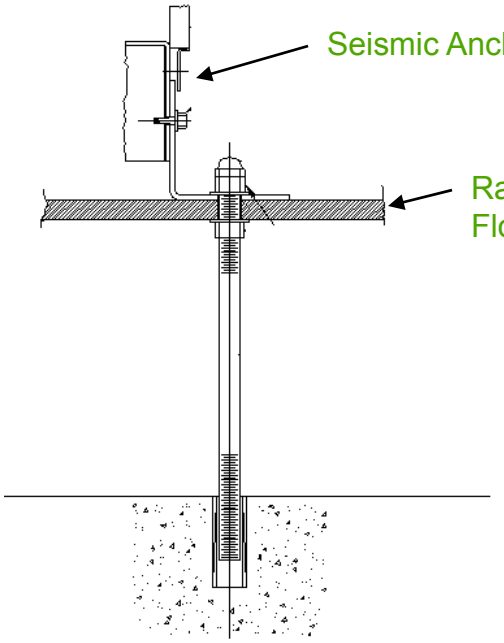
- **Available as field retrofit**
- **Monitors current on all individual panelboard branch circuits**
- **Each circuit will alarm at customizable (programmable) thresholds**
  - High current warning
  - Very high current / trip threshold warning
- **Currents for each breaker can be viewed on:**
  - MCM Display
  - Downloaded to PDA via MCM IR port
  - Output to the local RS485 serial port (up to 63 panel- boards can be daisy chained)

FLOOR STANDS & SEISMIC BRACING

- Floor stands to elevate the PDU/RPP to the height of the raised floor (12" or 18“)
- Seismic certified bracing secures the PDU/RPP



12” ,18”, 24” or any specified height



Questions