4160: THE GREEN 480

MEDIUM VOLTAGE ELECTRICAL SYSTEMS for DATA CENTERS

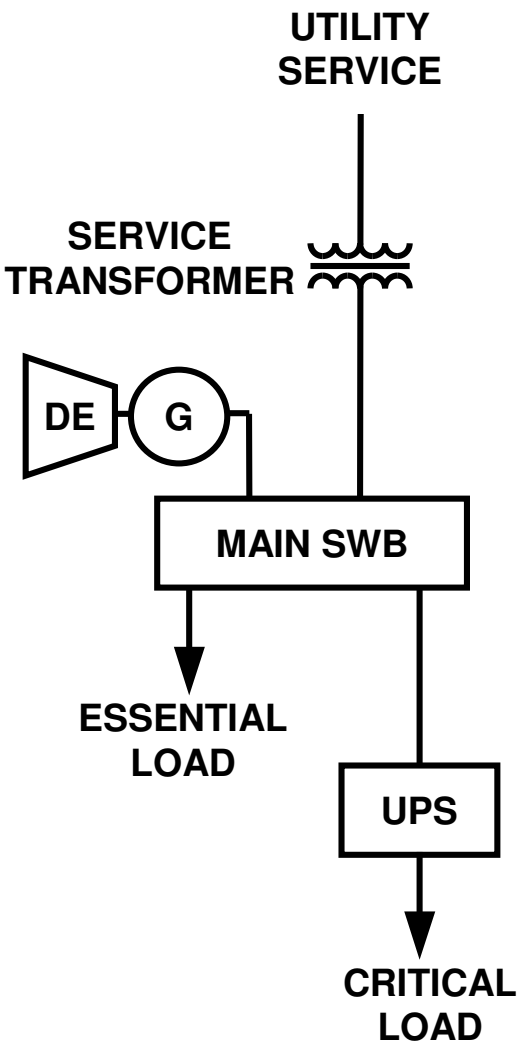
Michael Mosman, PE
Chief Technical Officer
CCG Facilities Integration Incorporated

AN OBSERVATION

The first choice for service and distribution voltage is 480 volts. Why?

- Traditional, safe design.
- Specs are already written around 480 V.
- UPS equipment is readily available at 480 V.
- Data centers are relatively compact for their high power density, therefore don't often require long runs at Medium Voltage for voltage drop reasons like campus-wide electrical distribution systems.

TYPICAL COMMERCIAL DESIGN



- Utility service, commonly Medium Voltage.
- Pad-mounted step-down service Transformer with LV underground secondary feeder.
- Main Switchboard with service main breaker.
- Optional backup Diesel Engine-Generator and transfer devices.
- Optional UPS system to carry critical loads through switching transfers.

LARGE LOW VOLTAGE DATA CENTER

TWO UTILITY SERVICES @ 35 kV, 30 MW

32 DIESEL ENGINE-GENERATORS @ 2.25 MW

16 SERVICE TRANSFORMERS @ 600 V, 5 MVA

MEDIUM VOLTAGE APPLICATION

Where are Medium Voltage distribution systems typically considered?

- In campus distribution where service runs are quite long.
- At Engine-Generator Switchgear when they are paralleled in massive numbers for capacity.
- In high-rise buildings where shaft space is a premium.
- NEVER in a computer room.

MEDIUM VOLTAGE APPLICATION

What are the perceptions of Medium Voltage switchgear when compared to Low Voltage switchboards?

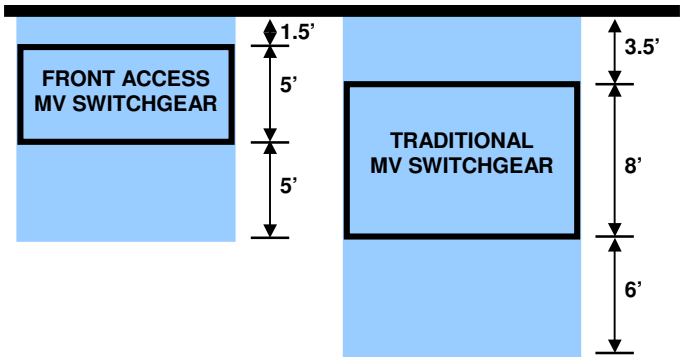
- More expensive.
- More dangerous.
- Harder to maintain.
- Less reliable.
- Not as flexible.
- Needs more space.

However, recent advancements in the technology of certain Medium Voltage equipment are changing the reality…

LINEAR ACTUATED MV BREAKERS

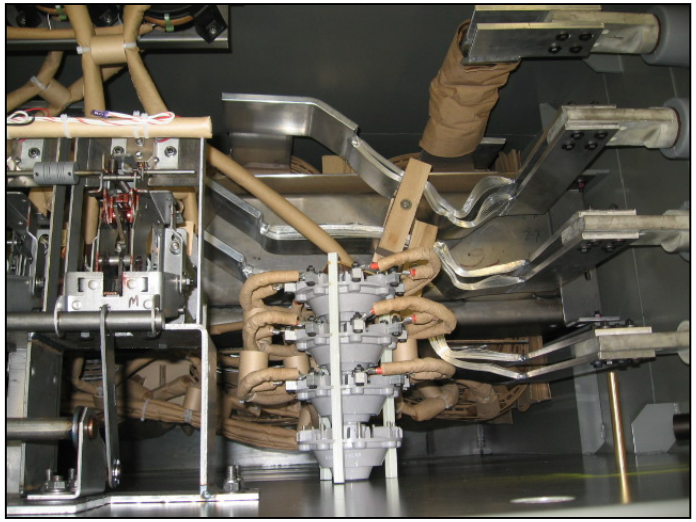
- Relatively new on market.
- Have the “look and feel” of Low Voltage breakers.
- Can have integral trip units.
- Can be found in 5kV, 15kV and 25kV Class.
- Fast tripping, typically 50ms.
- Far fewer moving parts.
- Endurance tests indicate they may operate up to 100,000 times without failure of breaker operating mechanisms.

FRONT ACCESSIBLE SWITCHGEAR



- New enclosure architecture requires ⅔ the space of traditional MV switchgear, even allowing for minimal space behind switchgear.
- Flexibility nearly equal to LV switchboards.
- Can be built with arc containment enclosures that vent explosive gas out the top or to the building exterior.
- Less costly than traditional switchgear.

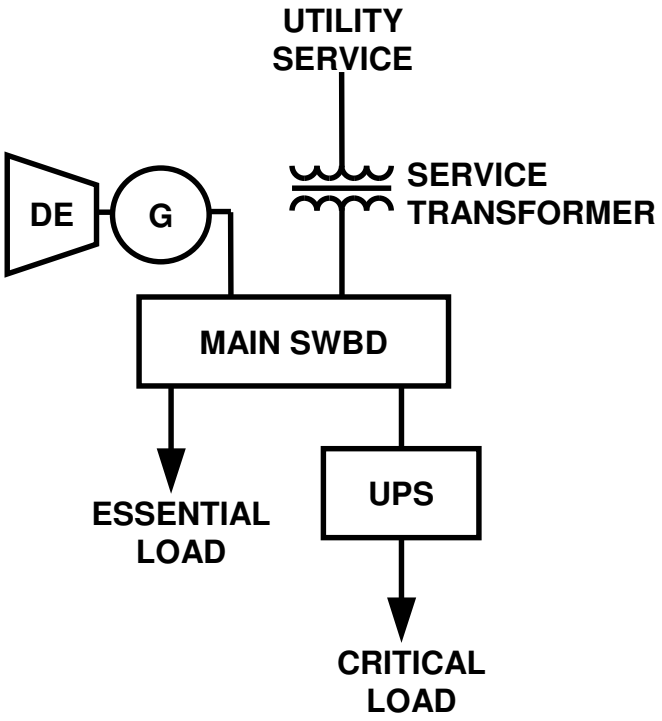
UPGRADED DISTRIBUTION TRANSFORMERS

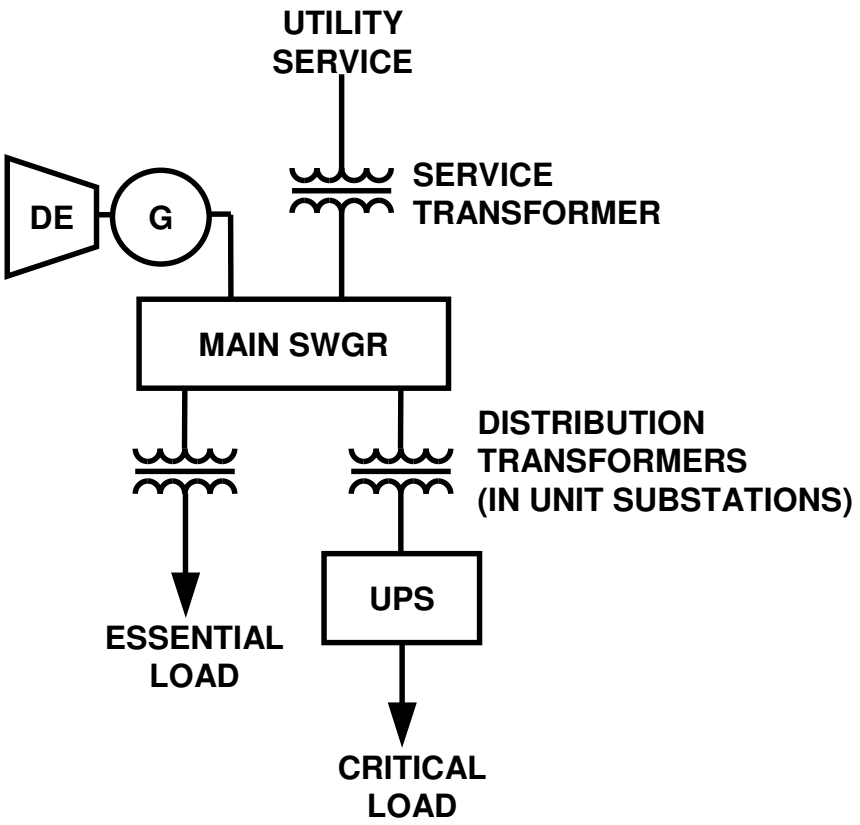


Photos courtesy of Cooper Power Systems

- New class of liquid-cooled transformers incorporated into unit substations.
- High flash point, biodegradable fluid (FR3®) safe for indoor application.
- High BIL (150 kV) suitable for vacuum breaker control without snubbers.
- Internal, fluid-immersed protection and switching.
- High efficiency, 99% or better.

TYPICAL LV & MV SYSTEMS





TYPICAL 480 VOLT SYSTEM

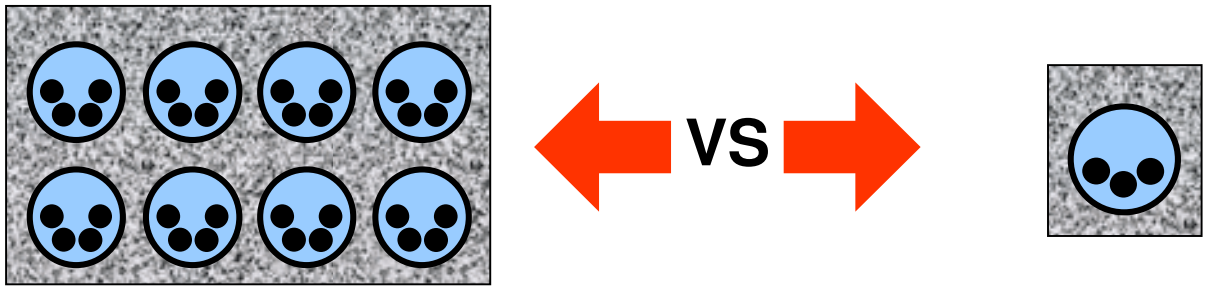
2500 kVA SERVICE TRANSFORMER
SECONDARY: 277/480 V, 3-PH, 4-W
2000 kW, 480 V STANDBY E-G
4000 AMP SWITCHBOARD
w/ 4000 A INSULATED CASE MAIN

TYPICAL 4I60 VOLT SYSTEM

2500 kVA SERVICE TRANSFORMER
SECONDARY: 4160 V, 3-PH, 3-W
2000 kW STANDBY E-G
1200 AMP SWITCHGEAR
w/ 600 A VACUUM BREAKER MAIN

COST COMPARISON #1 - FEEDERS

The greatest cost difference between systems is in the feeders. Both of these service entrance ductbanks are rated 2500 kVA.



480 VOLT, 3-PHASE, 4-WIRE

4000 AMP, 75' LONG
(8) SETS: (4) 750kCM XHHW in 4" PVC
600' of 4" PVC
2720' of 750kCM CU WIRE
6 CU YD of CONCRETE
(64) 600 V TERMINATIONS
$67,000*

4160 VOLT, 3-PHASE, 3-WIRE

500 AMP, 75' LONG
(3) 500kCM 5kV XLPE in 5" PVC
75' of 5" PVC
180' of 500kCM CU SHIELDED CABLE
2 CU YD of CONCRETE
(6) 5 kV TERMINATIONS
$9,000*

*** INCL. LABOR, MATERIAL, O&P (YOUR MILEAGE MAY VARY)**

COST COMPARISON #2 - SYSTEMS

TYPICAL 480 VOLT SYSTEM VS TYPICAL 4I60 VOLT SYSTEM

ENGINE-GENERATOR:
2000 kVA, 480 V
$650k

SWITCHBOARD:
4000 A, 480 V, w/ MAIN BKR, EG BKR & (2) FDR BKRS
$350k

MAJOR FEEDERS:
75’ 4000 A MAIN FDR,
100’ 3000 A EG FDR,
100’ 1200 A LOAD FDR &
50’ 2000 A LOAD FDR
$200k

DISTR. TRANSFORMERS:
NONE

$1,200k

ENGINE-GENERATOR:
2000 kVA, 4160 V
$700k

SWITCHGEAR LINEUP:
1200 A, 4160 V, w/ MAIN BKR, EG BKR & (2) FDR BKRS
$250k

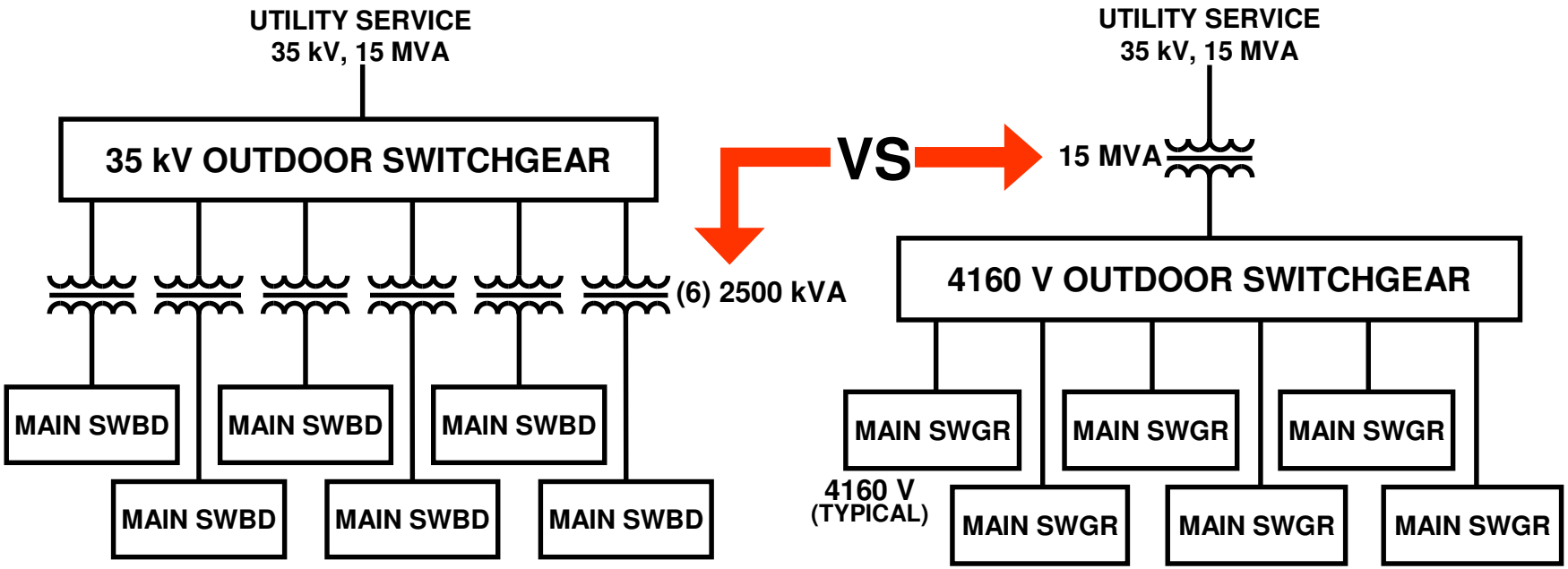
MAJOR FEEDERS:
75’ 500 A MAIN FDR,
100’ 500 A EG FDR &
150’ of LOAD FDRS @ 250 A
$50k

DISTR. TRANSFORMERS:
1500 kVA 480 V
1000 kVA 480 V
$100k

$1,100k

COST COMPARISON #3 – LARGE SYSTEMS

Large systems allow transformer consolidation.



(1) 35 kV SWGR, 1200 A:	$450k
(6) 35 kV FDRs, 200 A, 150':	$80k
(6) 2500 kVA TRANSF, 480V:	$400k
(6) 480 V FDRs, 4000 A, 75':	$400k
(6) TYPICAL 480 V SWBD & DISTRIBUTION SYSTEM:	$7,200k
TOTAL	$8,530k

(1) 15 MVA TRANSF, 4160V:	$250k
(1) 5 kV SWGR, 3000 A:	$550k
(1) 5 kV FDR, 3000 A, 100':	$20k
(6) 5 kV FDR'S, 500 A, 150':	$120k
(6) TYPICAL 4160V SWGR & DISTRIBUTION SYSTEM:	$6,600k
TOTAL	$7,540k

MEDIUM VOLTAGE ADVANTAGE

Besides the cost advantage, there are other reasons to consider MV systems:

- Greater safety – lower arc flash.
- Smaller footprint – new compact switchgear.
- Higher reliability – longer lasting breakers, cooler running ductbanks.
- Lower maintenance – simpler breakers, fewer terminations.
- Greater flexibility – choice of secondary voltages, longer feeders without huge cost.
- Greener building – less copper, PVC, steel.

ARC FLASH SAFETY

Counterintuitive to common belief, MV systems can have far less arc flash than equivalent power LV systems:

- Currents are lower in MV systems.
- The new MV linear breakers are faster than LV breakers of equal power rating.
- Arc currents in MV systems are typically closer to available fault levels than in LV systems. Breakers trip faster, more reliably.
- Faster tripping + lower currents produce far less arc energy.

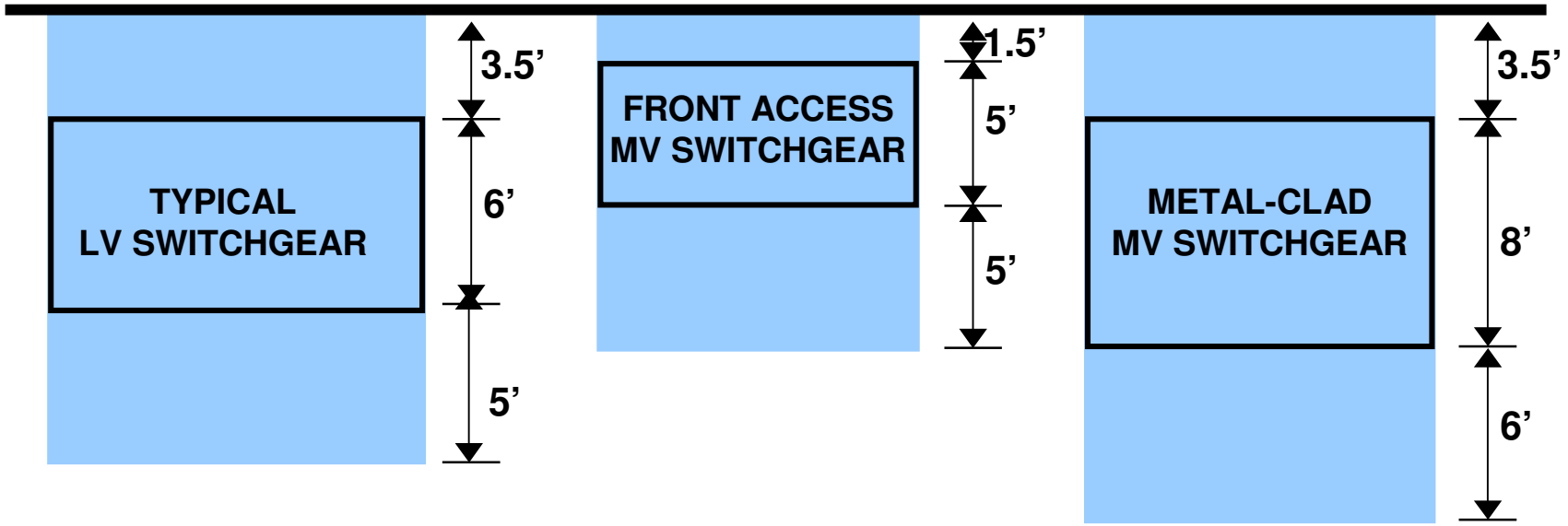
ARC FLASH STUDY

MAXIMUM ARCING FAULT	CASE #1 (LV)	CASE #2 (MV)
Utility Characteristics	34.5kV, 750MVA, X/R = 8	34.5kV, 750MVA, X/R = 8
Primary Protection	Vacuum fault interrupter, 400 A	Vacuum fault interrupter, 400 A
Service Transformer	2500 kVA	2500 kVA
Secondary Voltage	**480 volt, 3-ph, 4-wire, grounded**	**4160 volt, 3-ph, 3-wire, grounded**
Service Entrance Feeder	75' (8) 750kCM/ph, 600V XHHW in PVC	75' (1) 750kCM/ph, 5kV XLPE in PVC
Main Breaker (w/ integral long time & short time electronic trip)	Insulated Case, 4000A	Solenoid-Actuated Vacuum Bottle, 600A
Max Bolted 3-ph Fault Current	53.52 kA	6.41 kA
Max Arcing Fault Current at Bus	25.47 kA	6.27 kA
Normal Mode Arcing Time	0.4 seconds	0.4 seconds
Arc Flash Boundary Distance	180 inches	128 inches
Incident Energy	23.1 cal/cm^2	4.1 cal/cm^2
PPE Category	**3**	**1**

ARC FLASH STUDY

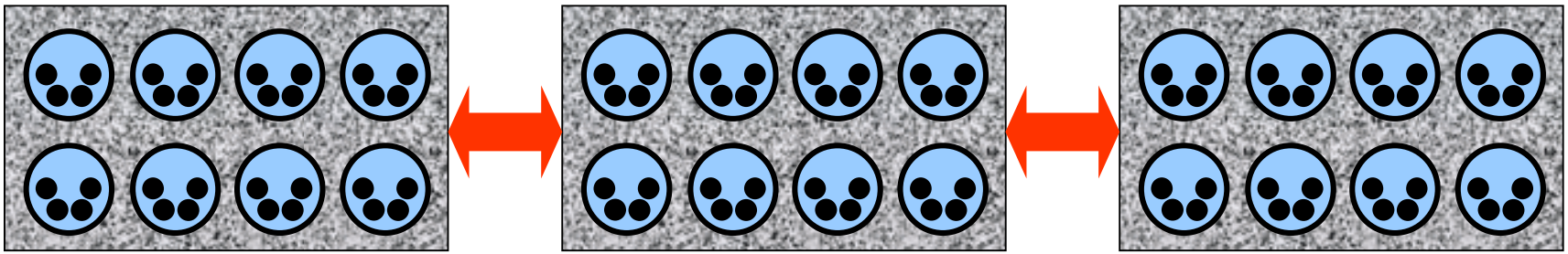
LIMITED ARCING FAULT	CASE #3 (LV)	CASE #4 (MV)
85% of Maximum Arching Fault Current	21.65 kA	5.33 kA
Arcing Time (@ 85% fault)	1.0 seconds	0.4 seconds
Arc Flash Boundary Distance (@ 85% fault)	297 inches	107 inches
Incident Energy (@ 85% fault)	48.5 cal/cm^2	3.5 cal/cm^2
PPE Category (@ 85% fault)	**Dangerous**	**1**
MAINTENANCE MODE	**CASE #5 (LV)**	**CASE #6 (MV)**
Maintenance Mode Arcing Time (max. fault)	0.06 seconds	0.06 seconds
Arc Flash Boundary Distance (maint. mode)	50 inches	18 inches
Incident Energy (maint. mode)	3.5 cal/cm^2	0.6 cal/cm^2
PPE Category (maint. mode)	**1**	**0**

SWITCHGEAR FOOTPRINT



Front accessible Medium Voltage switchgear is smaller than both traditional metal-clad switchgear AND Low Voltage switchboards of equivalent power.

DUCTBANK INTEGRITY



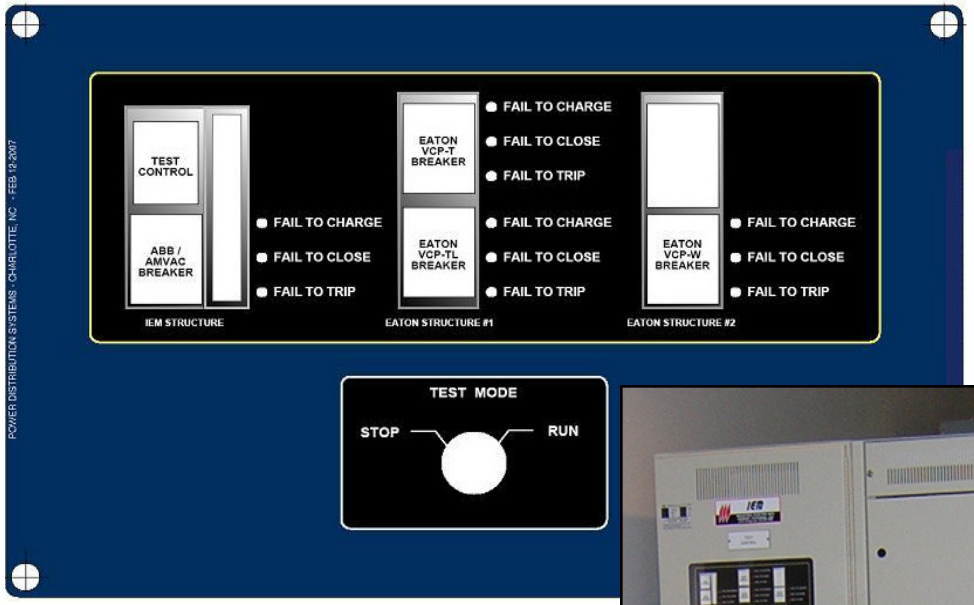
MUTUAL HEATING

NO MUTUAL HEATING

Multiple underground LV ductbanks close together (common in large facilities) can be destroyed by mutual heating.
MV ductbanks are far less susceptible.

BREAKER EVALUATION

600 volt breaker endurance testing switchboard w/four brands of insulated-case breakers, 9/2005.



5 kV breaker endurance testing switchgear lineup w/two metal-clad breakers and two linear-actuator breakers, 2/2007.

Photos courtesy of Power Distribution Systems.

BREAKER RELIABILITY

600 VOLT INSULATED CASE BREAKER
SQUARE D MASTERPACT NW

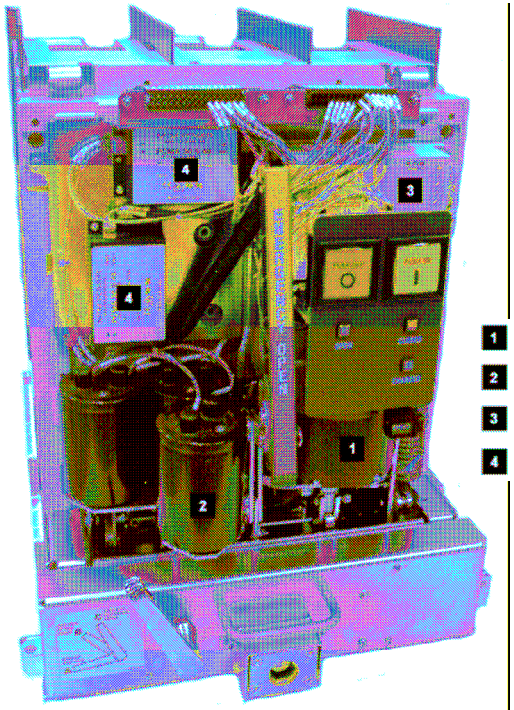
VS

MV MAG-ACTUATED VACUUM BREAKER
ABB VM-1

Endurance test results:

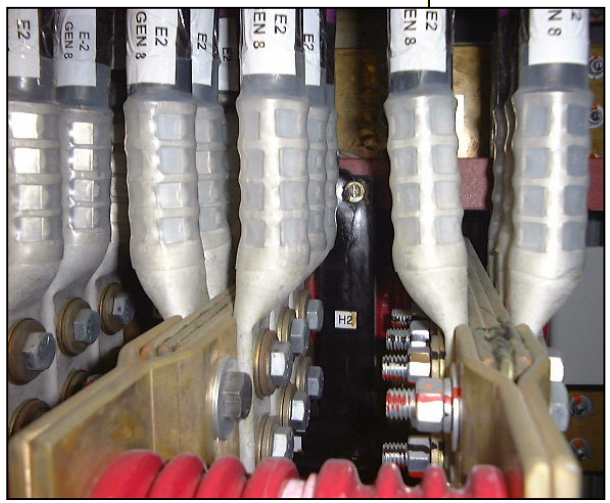
- The best 480 V breaker performed nearly 25,000 operations before failure.
- The best 4160 V breaker went over 70,000 operations before testing was stopped.

MAINTAINABILITY



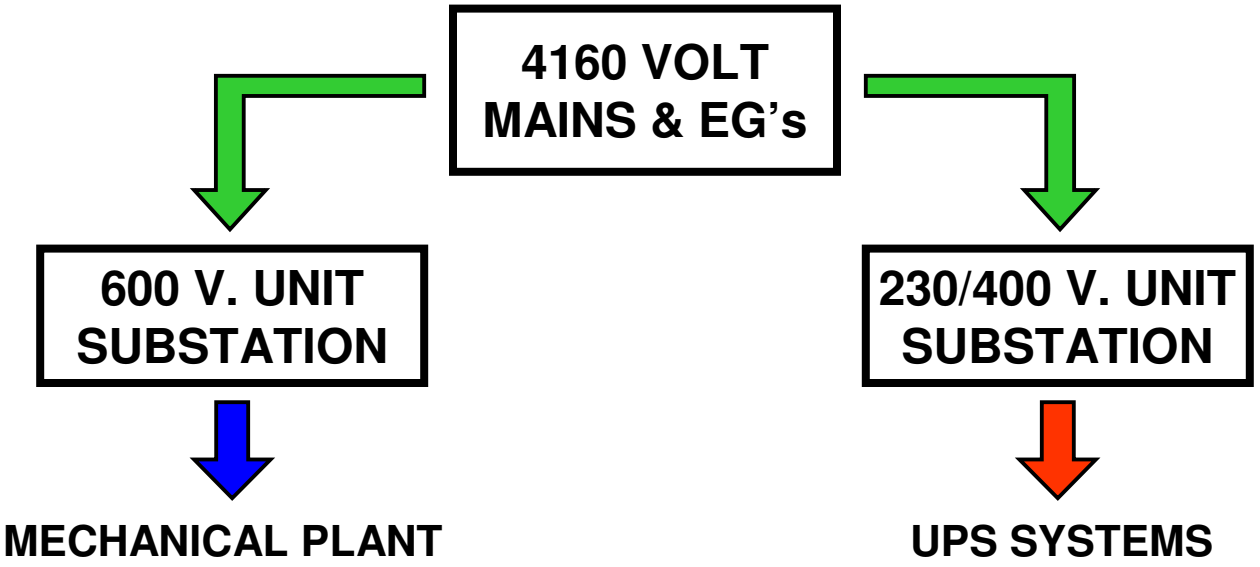
YES

NO



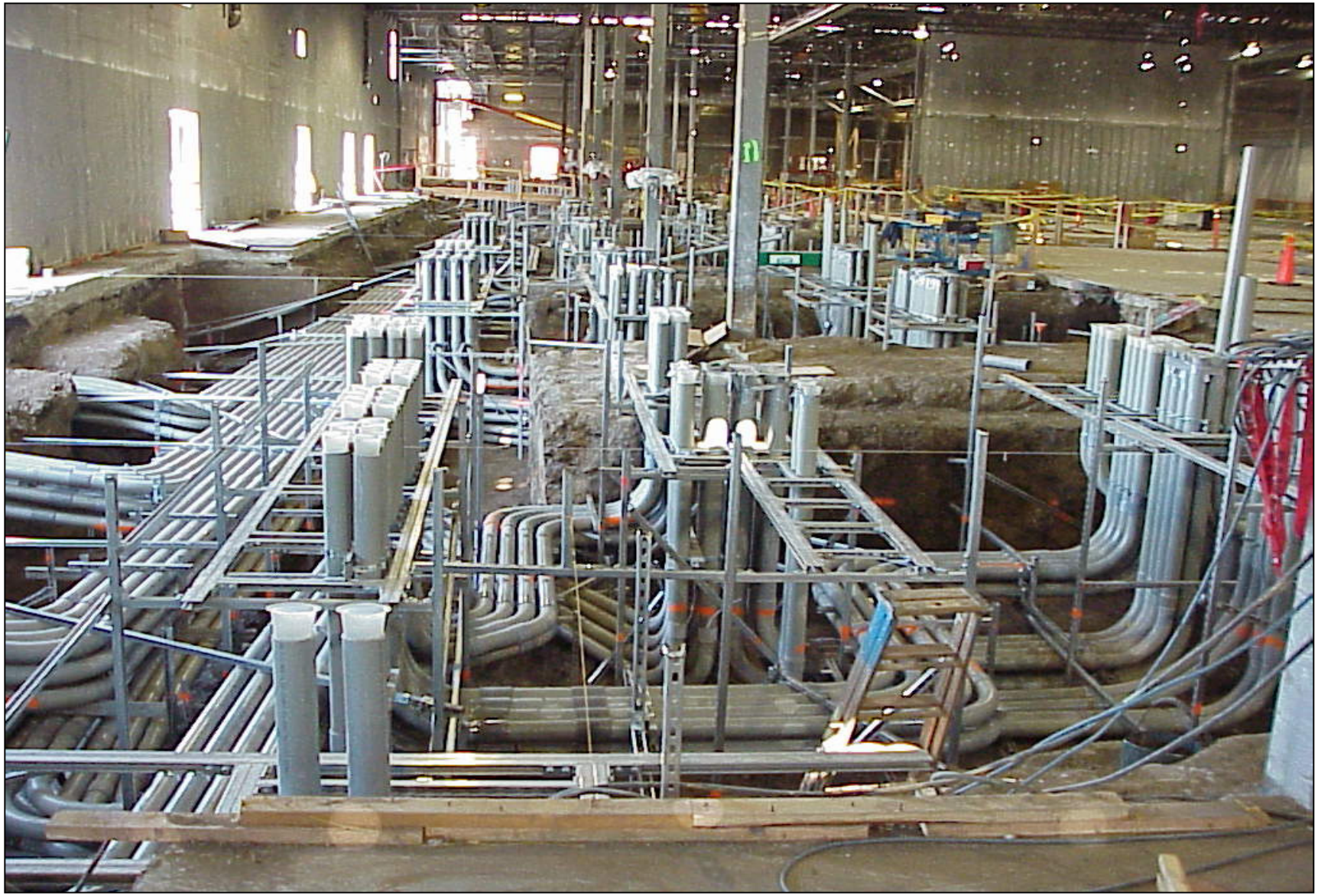
- Linear actuator type breakers have fewer parts, simpler construction than molded case LV breakers.
- Medium Voltage switchgear have fewer bus connections and wire terminations than LV switchboards.
- MV switchgear have less heat related issues than LV switchboards.

FLEXIBILITY



- Providing separate transformation for essential loads and critical loads allows the secondary voltage to be tailored to load requirements.
- Medium Voltage main and generator feeders allow the distance to load to grow without huge increase in cost and losses.

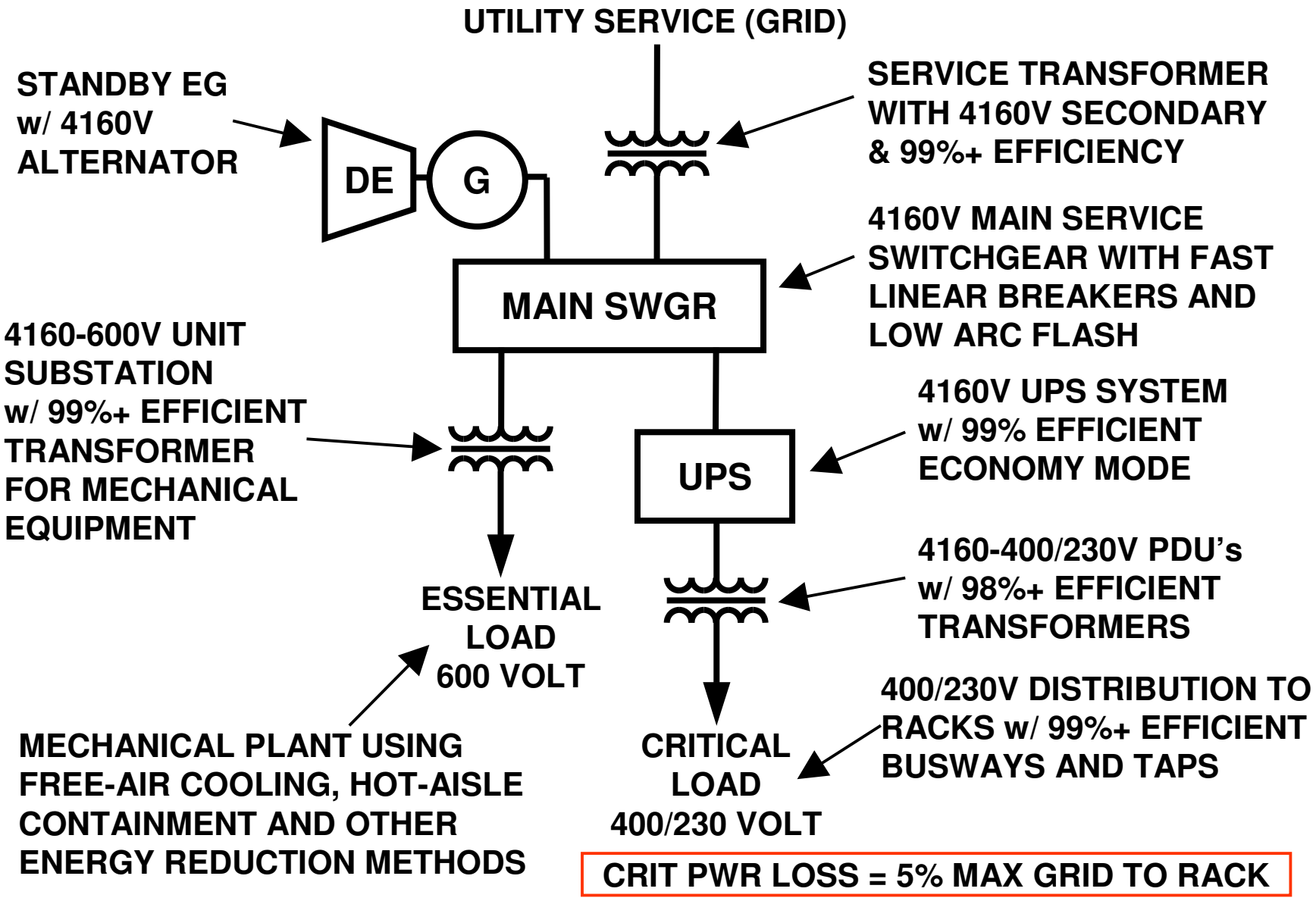
SUSTAINABLE CONSTRUCTION?



GREEN IDEAS

- Eliminate 80% of the PVC and copper content in data center electrical distribution.
- Reduce transformer heat losses by 60%, and major feeder losses by a factor of 50.
- Make electrical equipment rooms 25% smaller and require less building structure.
- Bring total critical power losses between utility grid and computer rack under 5% by:
  - Developing 4160 volt UPS systems and,
  - Using 4160 – 230/400 volt PDU's in the computer room.

THE TRULY GREEN DATA CENTER



QUESTIONS AND COMMENTS

4160

THE GREEN 480

THANK YOU

FACILITIES INTEGRATION
INCORPORATED

Michael Mosman, PE
mmosman@ccgfacilities.com