PILLER
Power Systems

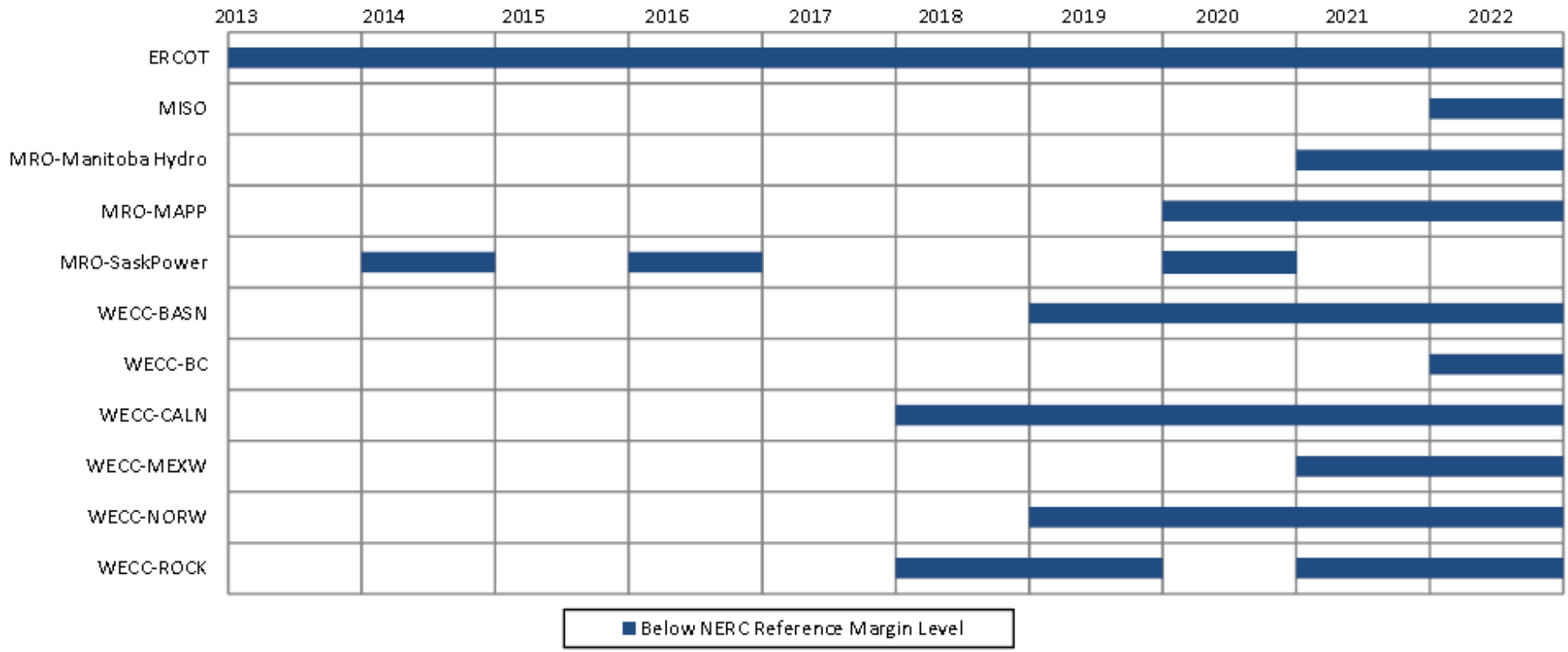
Stabilized Cogeneration

Bud Leavell – Piller USA Inc.

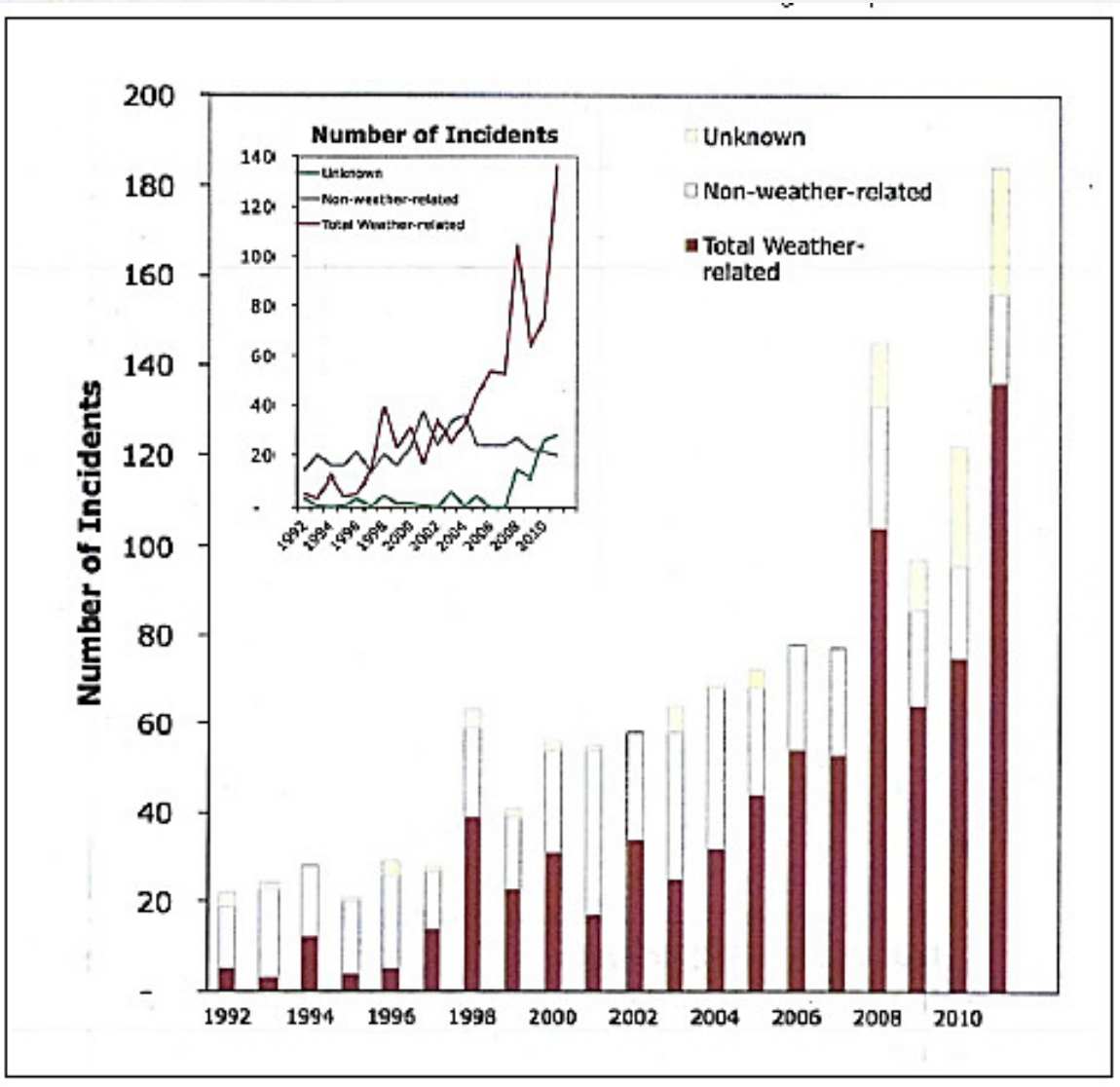
WHY?

- Coming Grid Instability!
- Worst prognosis is Texas
- Nationally, it is coming as well

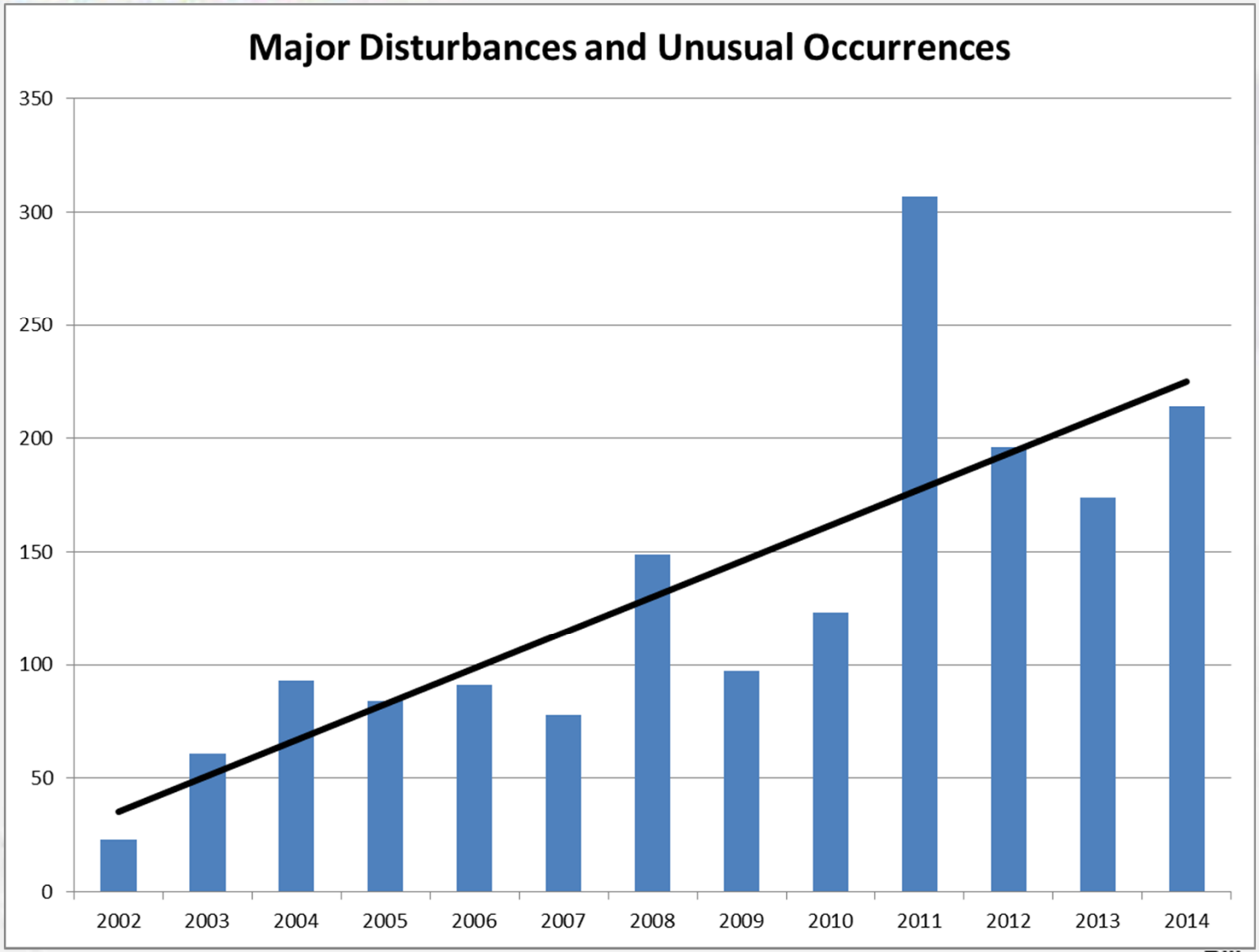
NERC 2012 Long Term Reliability Assessment



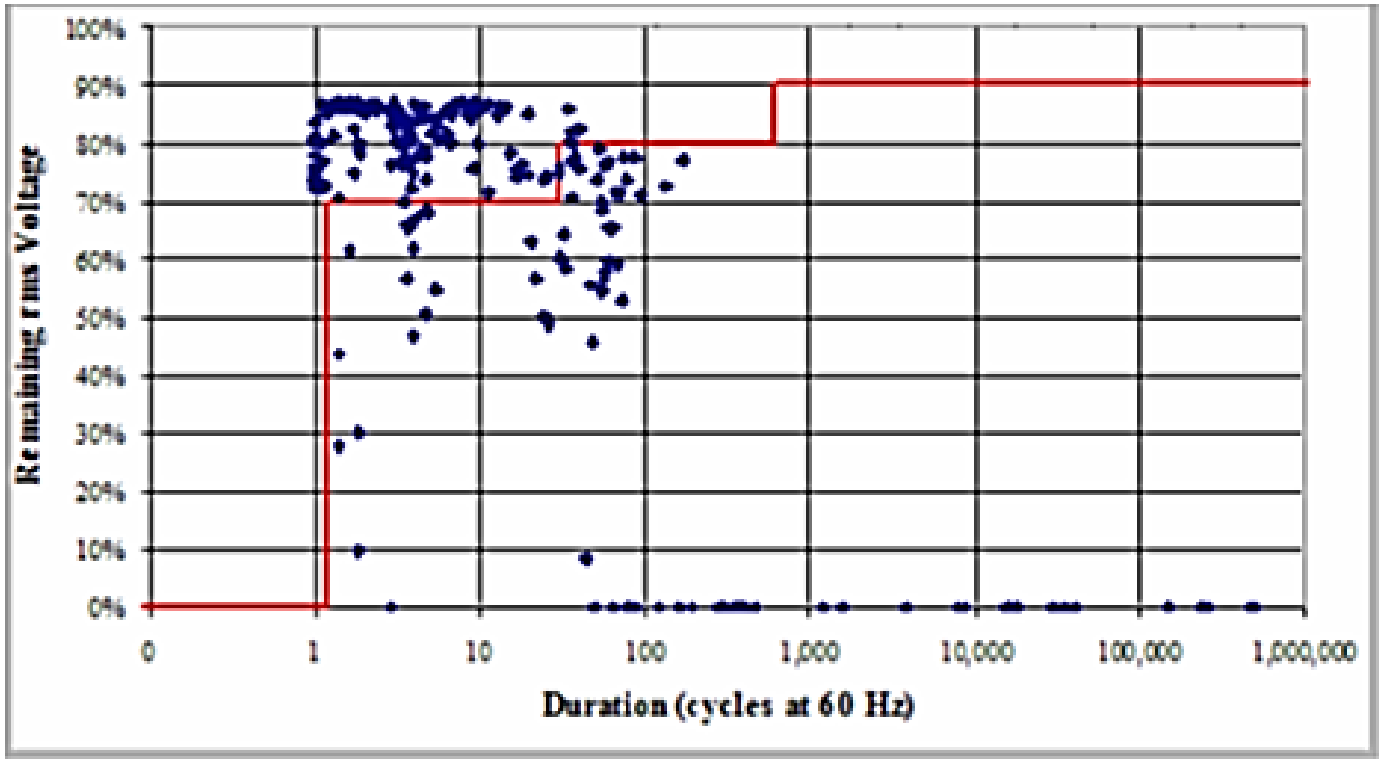
Growing Grid Instability
Significant US Grid Weather-Related Grid Disturbances



Growing Grid Instability

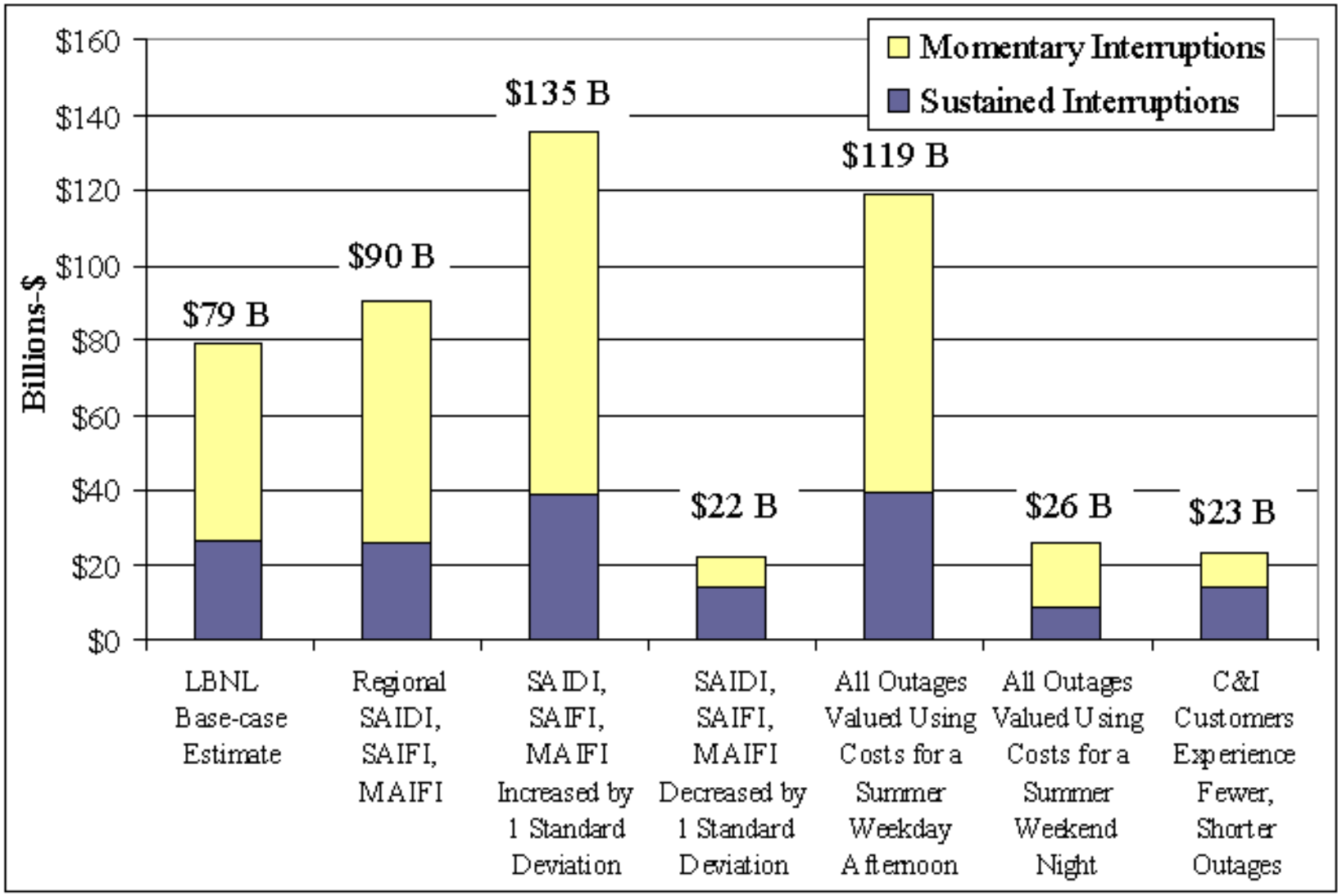


Duration of Power Outages



Source: **ERNEST ORLANDO LAWRENCE BERKELEY NATIONAL LABORATORY**
Understanding the Cost of Power Interruptions to U.S. Electricity Consumers

Kristina Hamachi LaCommare and Joseph H. Eto



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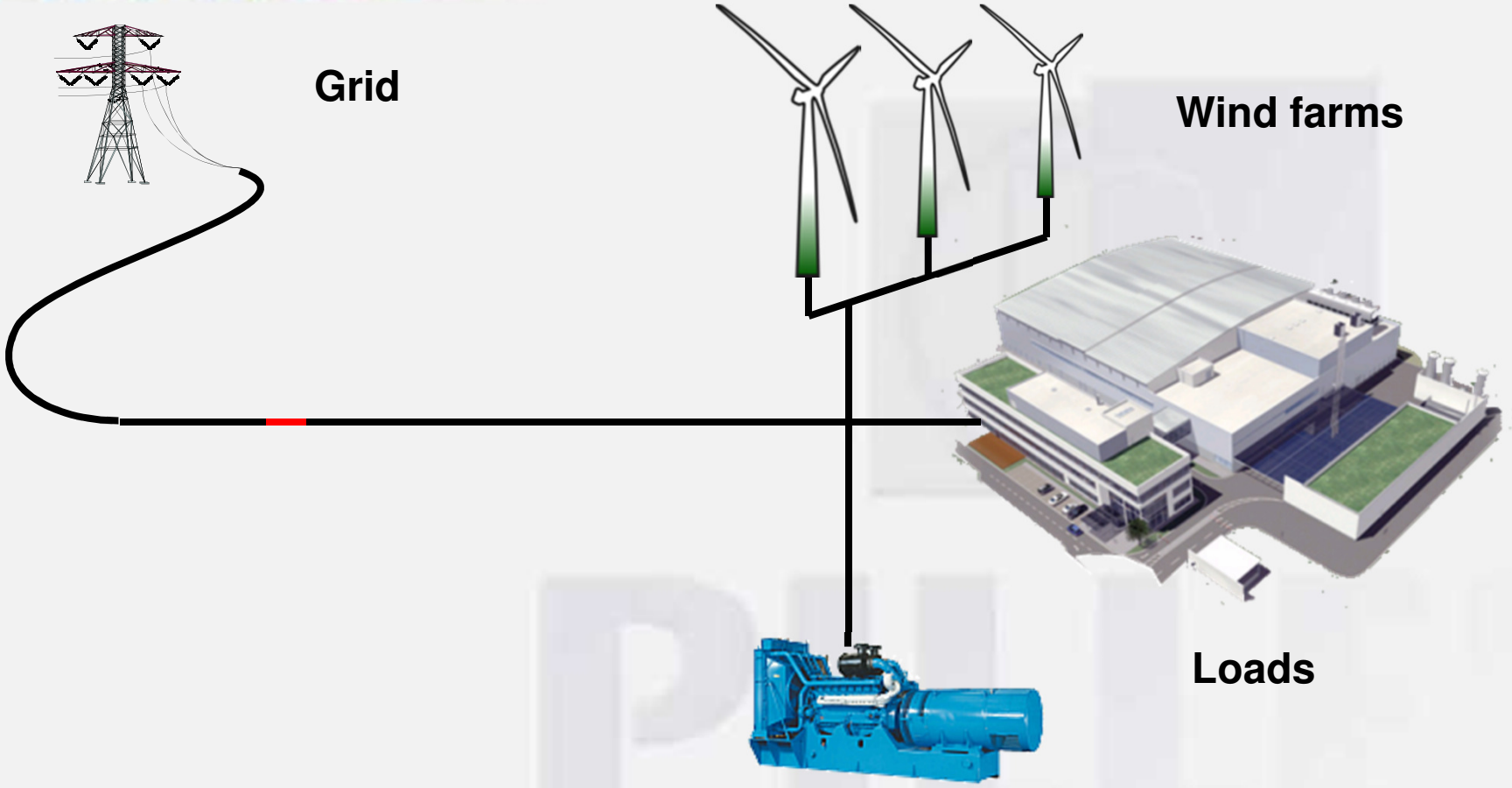
Costs tend to be driven by the frequency rather than the duration of reliability events.

One Possible Solution: Co-Generation

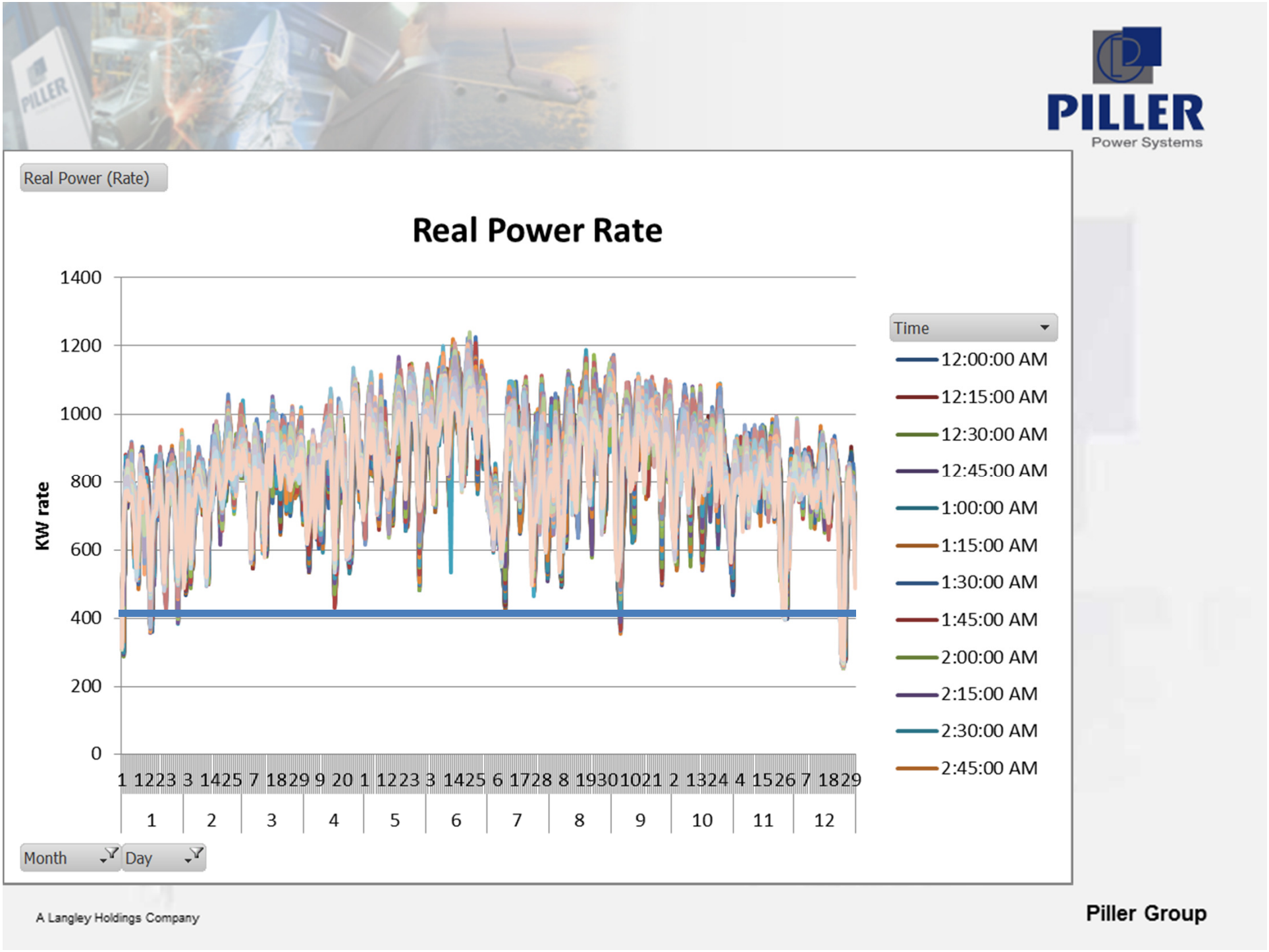


Factors Driving the Expansion of Cogeneration

- Low Cost of Natural Gas
  - Week ending Apr 8, 2016 Henry Hub = $1.96/MMBtu
- Promise of greater thermal efficiency
  - thermal efficiencies > 70% *(HHV)*
- Reduced Cost of power generation
- Environmental
  - EPA driving power generation toward natural gas
- Distributed Generation contributing to grid stability by exporting power to the grid

Issues Related to Co-Generation

- Machinery means STEP LOADS!



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A Langley Holdings Company

Piller Group

Issues Related to Co-Generation

- Machinery means STEP LOADS!
- Machinery means Power Factor issues.

$$P = EI\sqrt{3}\,cos\theta$$

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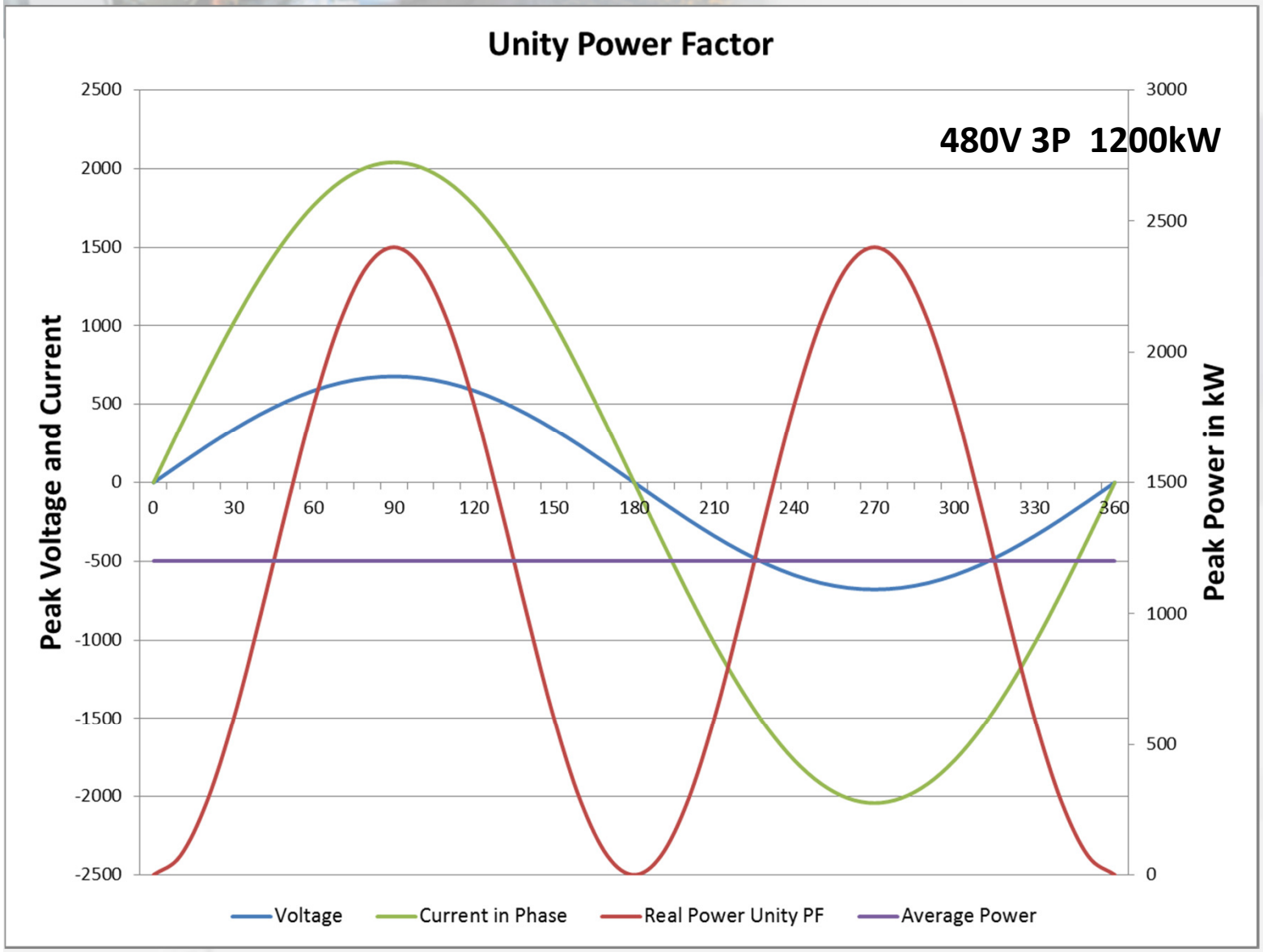

$$S = EI\sqrt{3}$$

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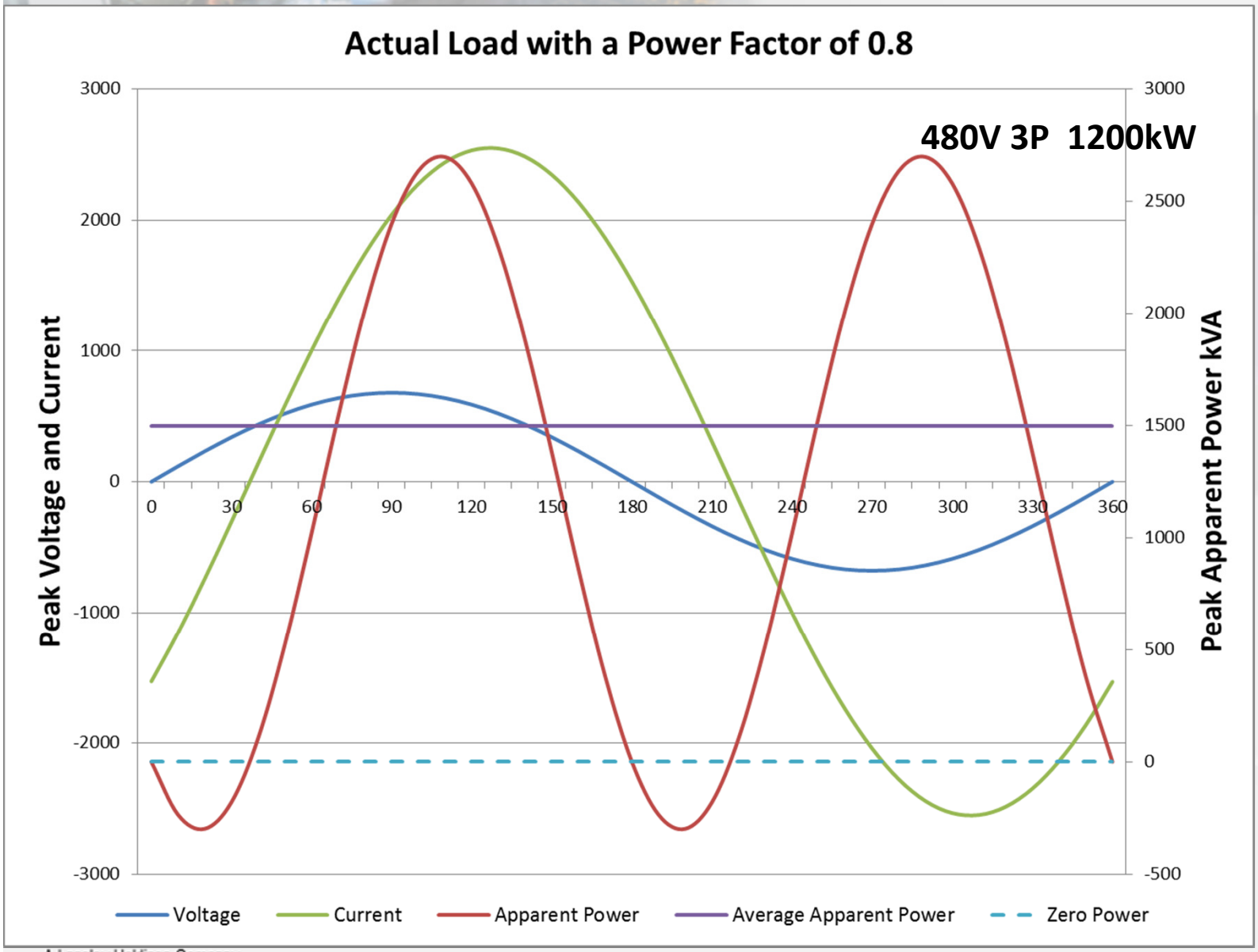

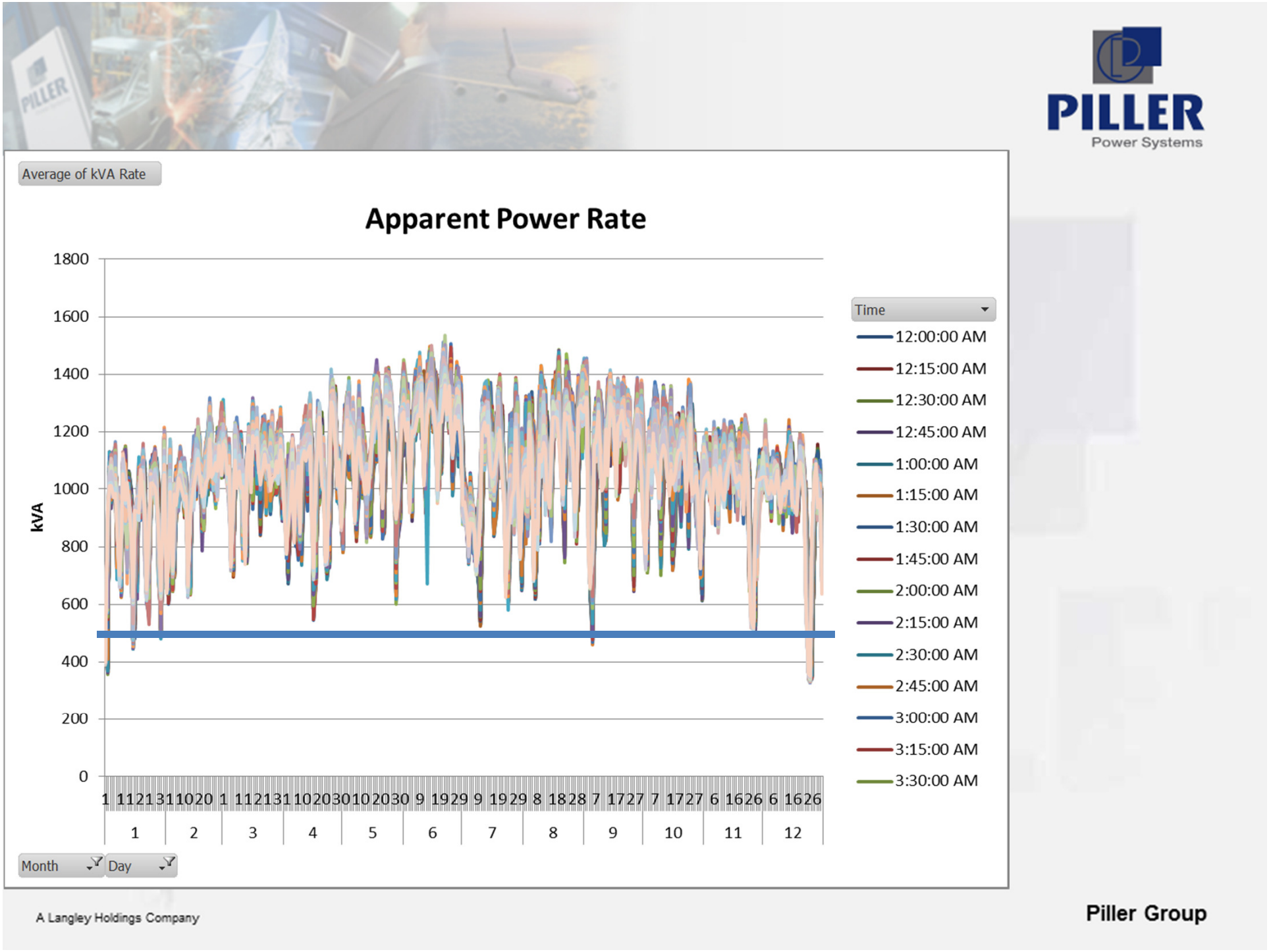
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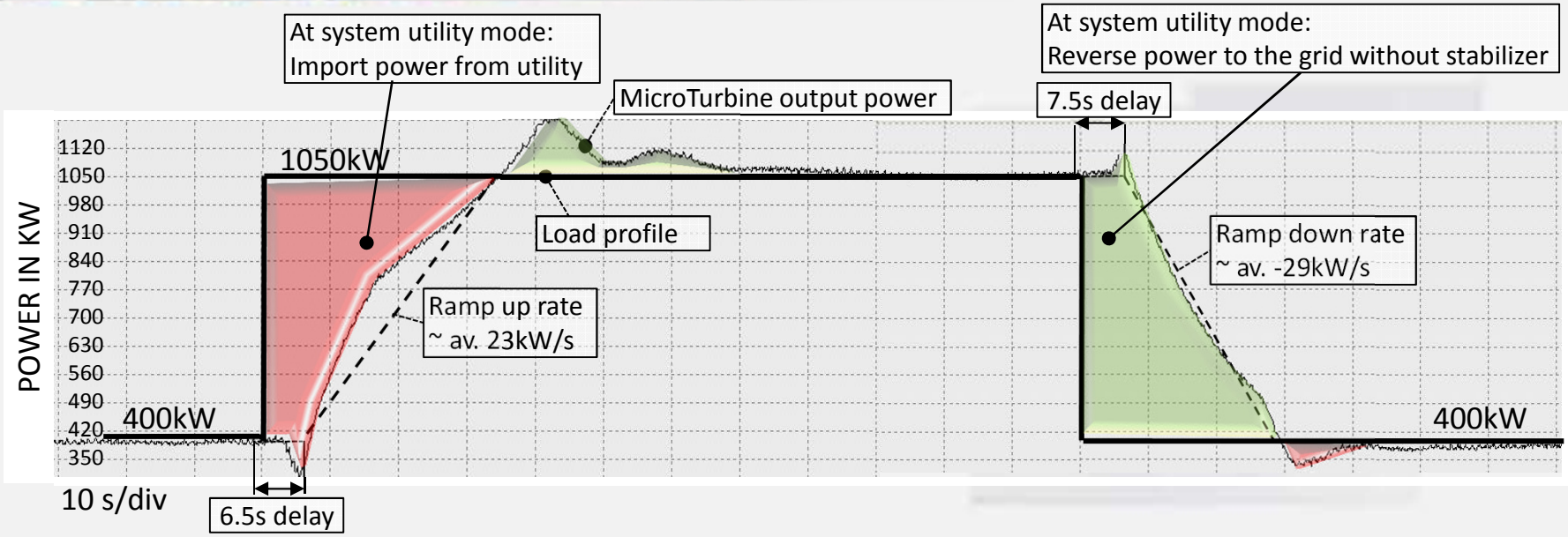
Average of kVA Rate
Apparent Power Rate
kVA
1800
1600
1400
1200
1000
800
600
400
200
0
Time
12:00:00 AM
12:15:00 AM
12:30:00 AM
12:45:00 AM
1:00:00 AM
1:15:00 AM
1:30:00 AM
1:45:00 AM
2:00:00 AM
2:15:00 AM
2:30:00 AM
2:45:00 AM
3:00:00 AM
3:15:00 AM
3:30:00 AM
1 2 3 4 5 6 7 8 9 10 11 12
Month
Day
A Langley Holdings Company
Piller Group

Issues Related to Co-Generation

- Machinery means STEP LOADS!
- Machinery means Power Factor issues.
  - Generators do not like leading pf!
- Poor dynamic response of N.G. fired power plants
  - Sometimes as slow as 10kW/sec

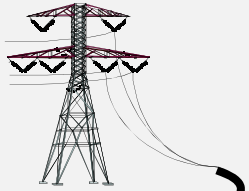
Block loading & unloading on MicroTurbine system



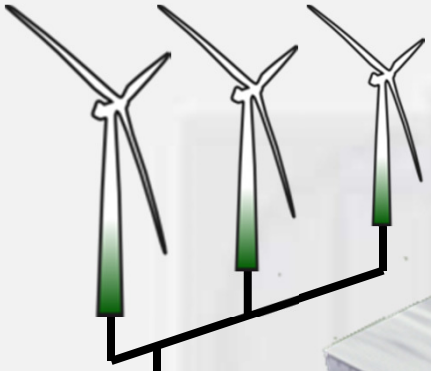
Issues Related to Co-Generation

- Machinery means STEP LOADS!
- Machinery means Power Factor issues.
  - Generators do not like leading pf!
- Poor dynamic response of N.G. fired power plants
  - Sometimes as slow as 10kW/sec
  - Step loads cause voltage and frequency instability
  - Faults on either side can 'KILL' the plant.
- Inefficient sizing to compensate for dynamic response
- Power has to go somewhere!
  - Load banks required?
- No security from utility interruptions?
  - True with at least some co-gen solutions

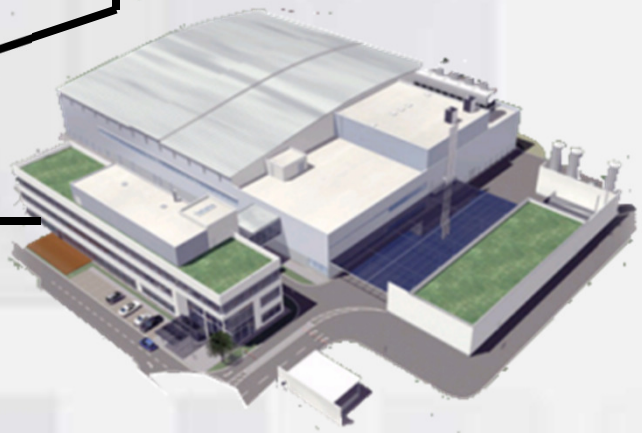
Stabilized: Co-Generation



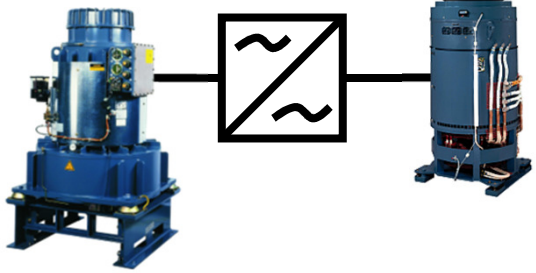
Grid



Wind farms



Loads



Rotary UPS
with Bi-Directional
Kinetic Energy Store

Natural Gas engines,
turbines, Fuel Cells etc.

What is Rotary UPS?

- A rotating machine feeding the load – ROTARY
- A static inverter feeding the load – STATIC
- Battery – energy storage
- Flywheels – energy storage
- Induction Coupling – energy storage
- Any UPS can be with or without a back-up generator

- "In a Rotary UPS, during all modes of operation**, the load is fed directly from a synchronous generator or motor generator** .....Hence, the distinction between a Static and a Rotary does not lie in the use of batteries or flywheels as a short-term emergency power source; rather it is based on the method through which the output power is derived"
-

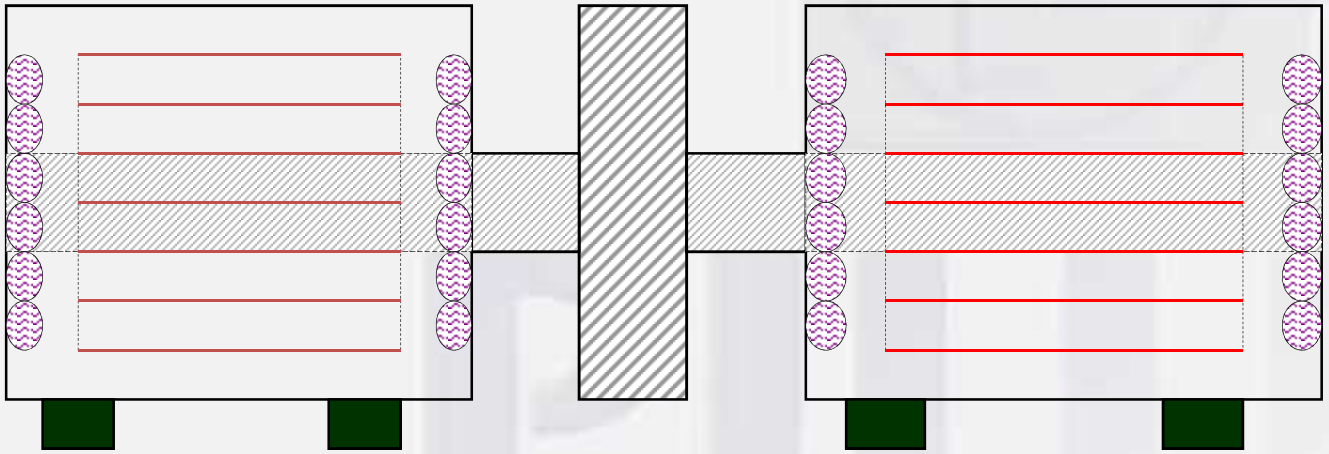
2008 Frost and Sullivan

Properties of Synchronous Machines

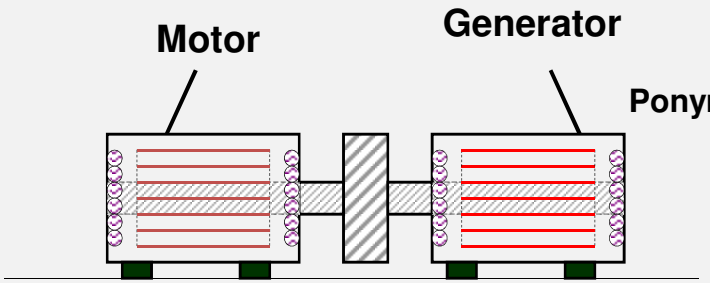
- Unlike inductive motors, the rotor turns at the synchronous speed. No SLIP
- An external mechanism must be provided to start the machine and bring it up to 95% of synchronous speed before excitation.
- As an Unloaded Synchronous Motor:
  - under-excitation = inductive *(absorbs VARs)*
  - over-excitation = capacitive *(source of VARs)*
- When driven mechanically with excitation becomes a generator.

Evolution of the Motor Generator

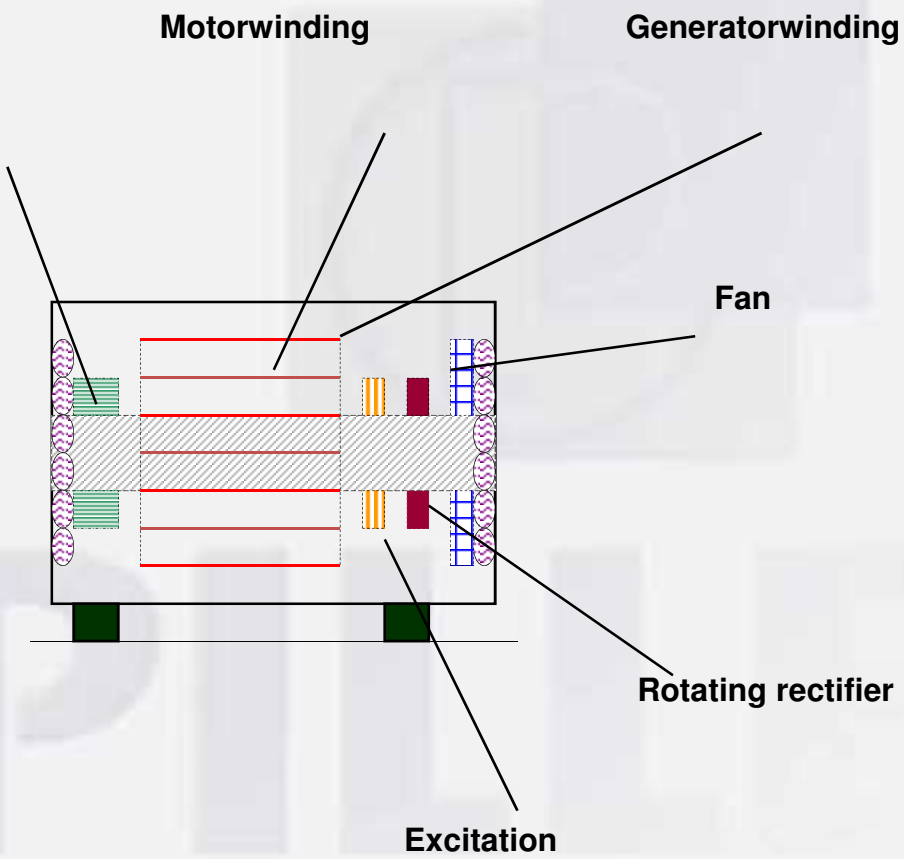
Motor Generator / Motor Generator



Piller UNIBLOCK
Motor Generator

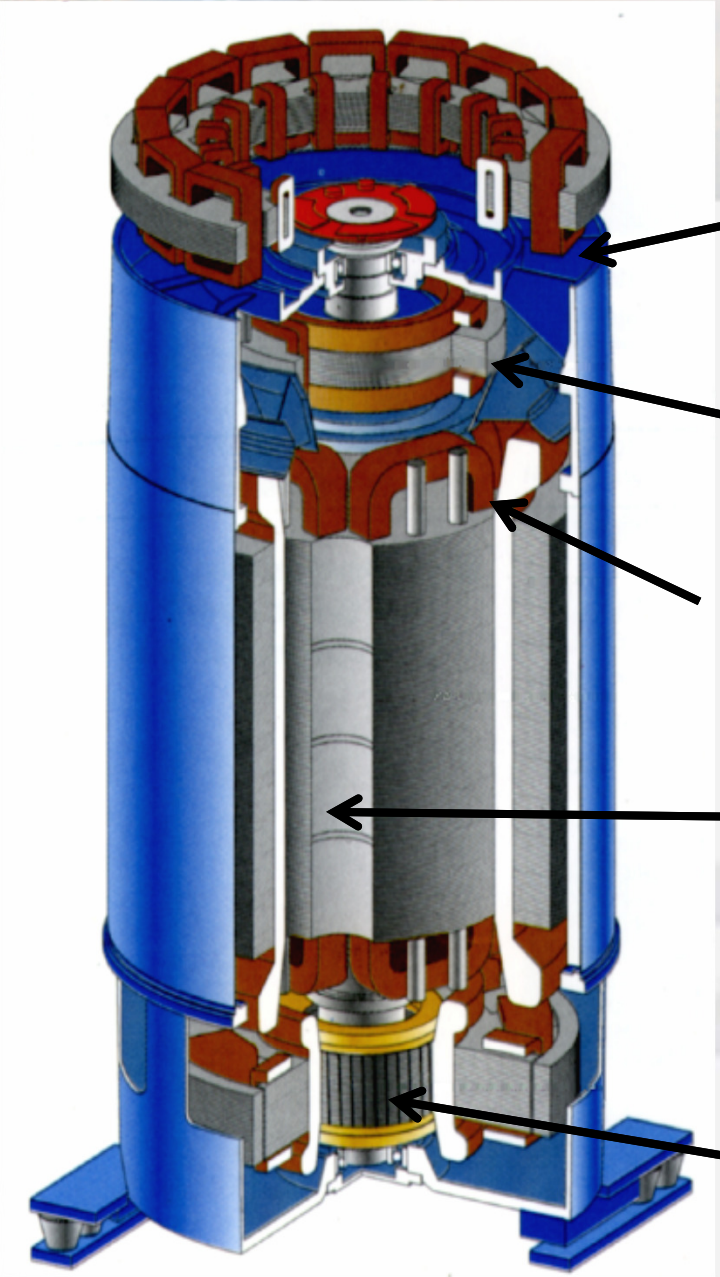


Hybrid machine developed by PILLER



Unique and highly reliable system including motor and generator

UniBlock



System fan

Brushless excitation

Motor and generator windings
in a common stator

Common rotor
with damper winding

Pony motor

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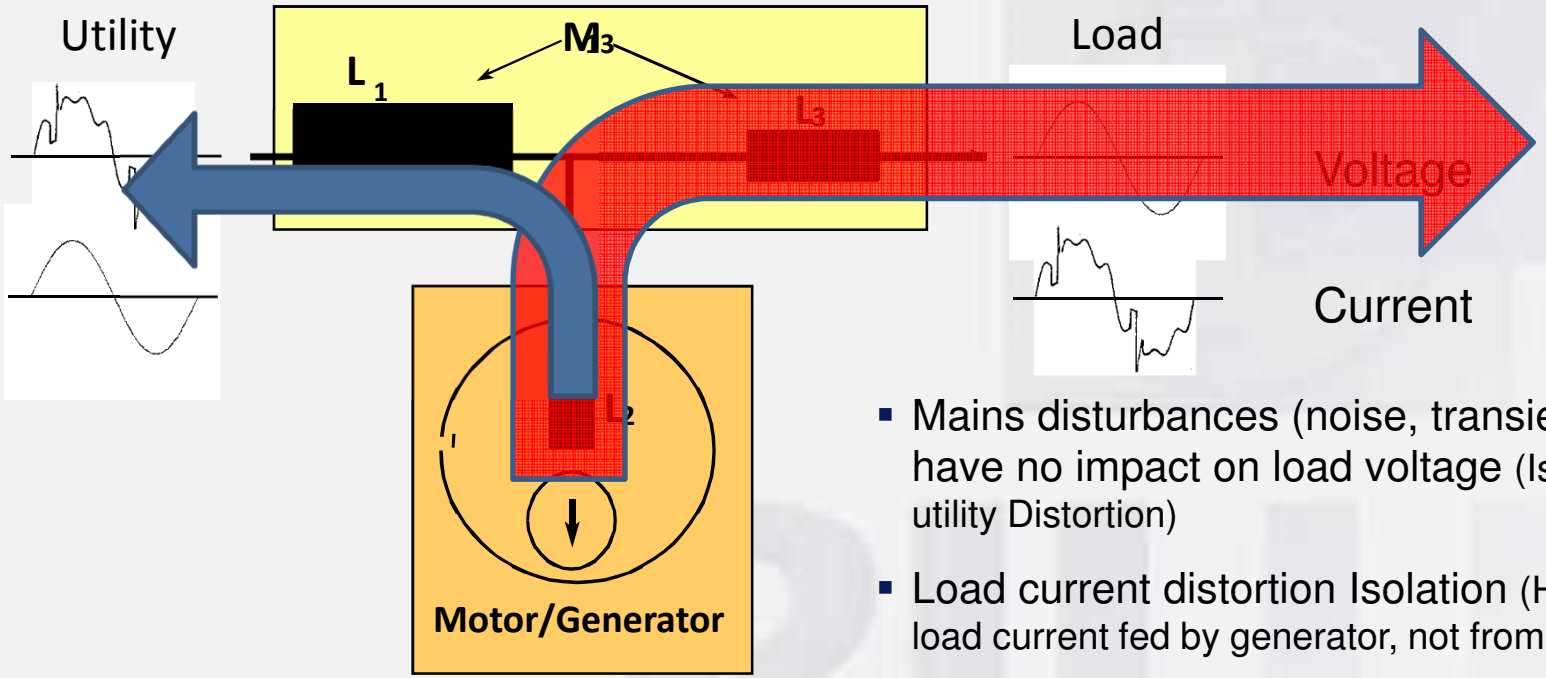
Power Systems

The UNIBLOCK-T: Coupling Choke

Provides Bi Directional Isolation



- Mains disturbances (noise, transients) have no impact on load voltage (Isolation on utility Distortion)
- Load current distortion Isolation (Harmonic load current fed by generator, not from mains)
- In event of a mains short, the choke limits utility fault contribution (Forward fault current up to14X) No need to go into bypass.

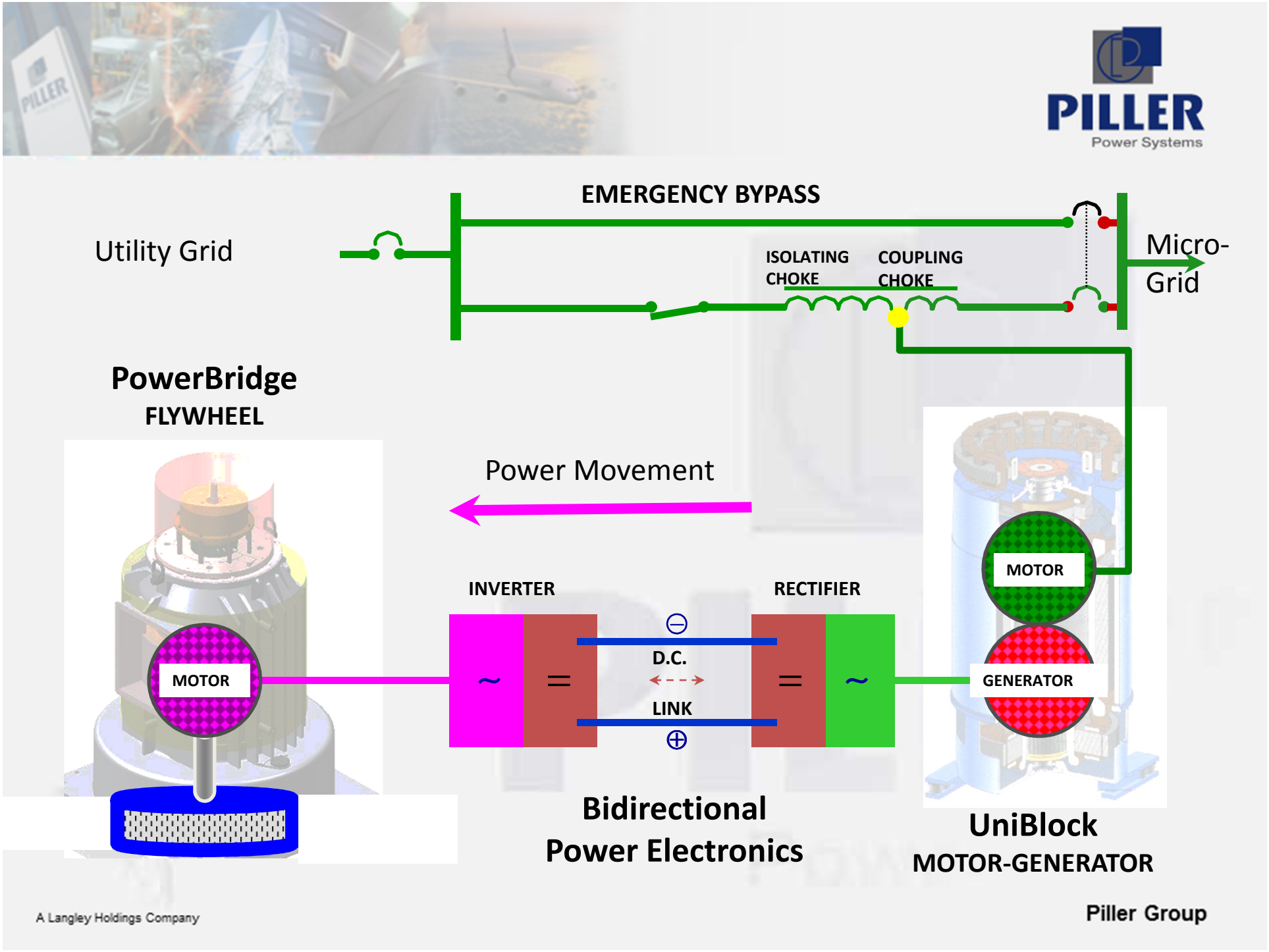
Newton's First Law of Motion

Every object in a state of uniform motion tends to remain in that state of motion unless an external force is applied to it.

POWERBRIDGE Energy Store available in 16.5MJ, and 21MJ

PILLER Power Systems

- 16.5 MJs Energy store. (~13s at 1336kW/1670kVA)
- Can be paralleled for use with larger UniBlocks
- Electrically coupled bi-directional power flow provides stabilization action
- Very fast re-charge
- Simple design - two load bearings
- Low loss Helium environment
- Very small footprint – high power density
- Capable of absorbing just as much energy as it can deliver and at the same rate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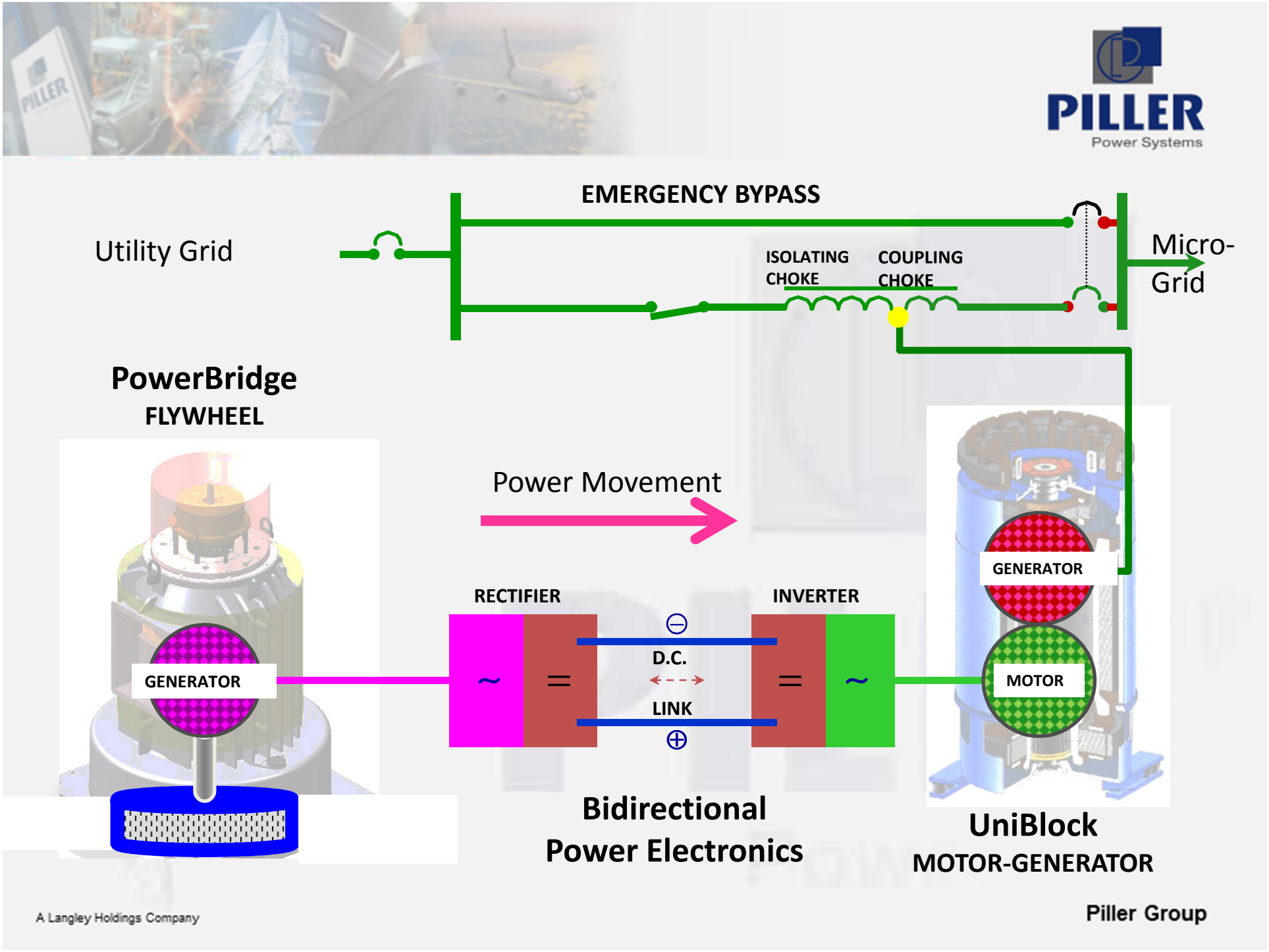
Power Systems
EMERGENCY BYPASS
Utility Grid
ISOLATING CHOKE
COUPLING CHOKE
Micro-Grid
PowerBridge
FLYWHEEL
Power Movement
INVERTER
RECTIFIER
MOTOR
D.C.
LINK
GENERATOR
MOTOR
Bidirectional
Power Electronics
UniBlock
MOTOR-GENERATOR
A Langley Holdings Company
Piller Group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Power Systems
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ISOLATING CHOKE
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Micro-Grid
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Power Movement
GENERATOR
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The UNIBLOCK UBT With PowerBridge Kinetic Flywheel Energy Store

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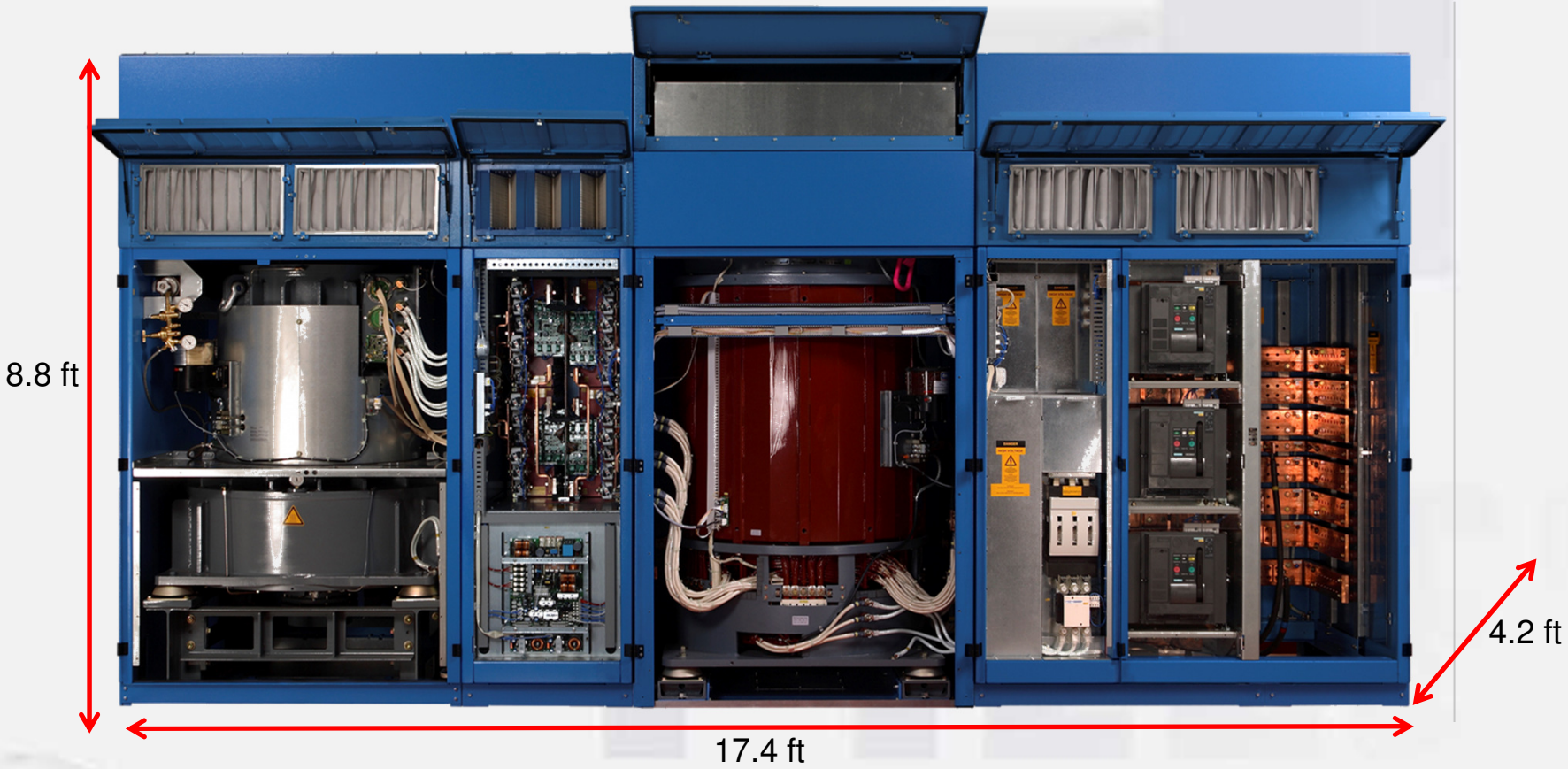
Power Systems



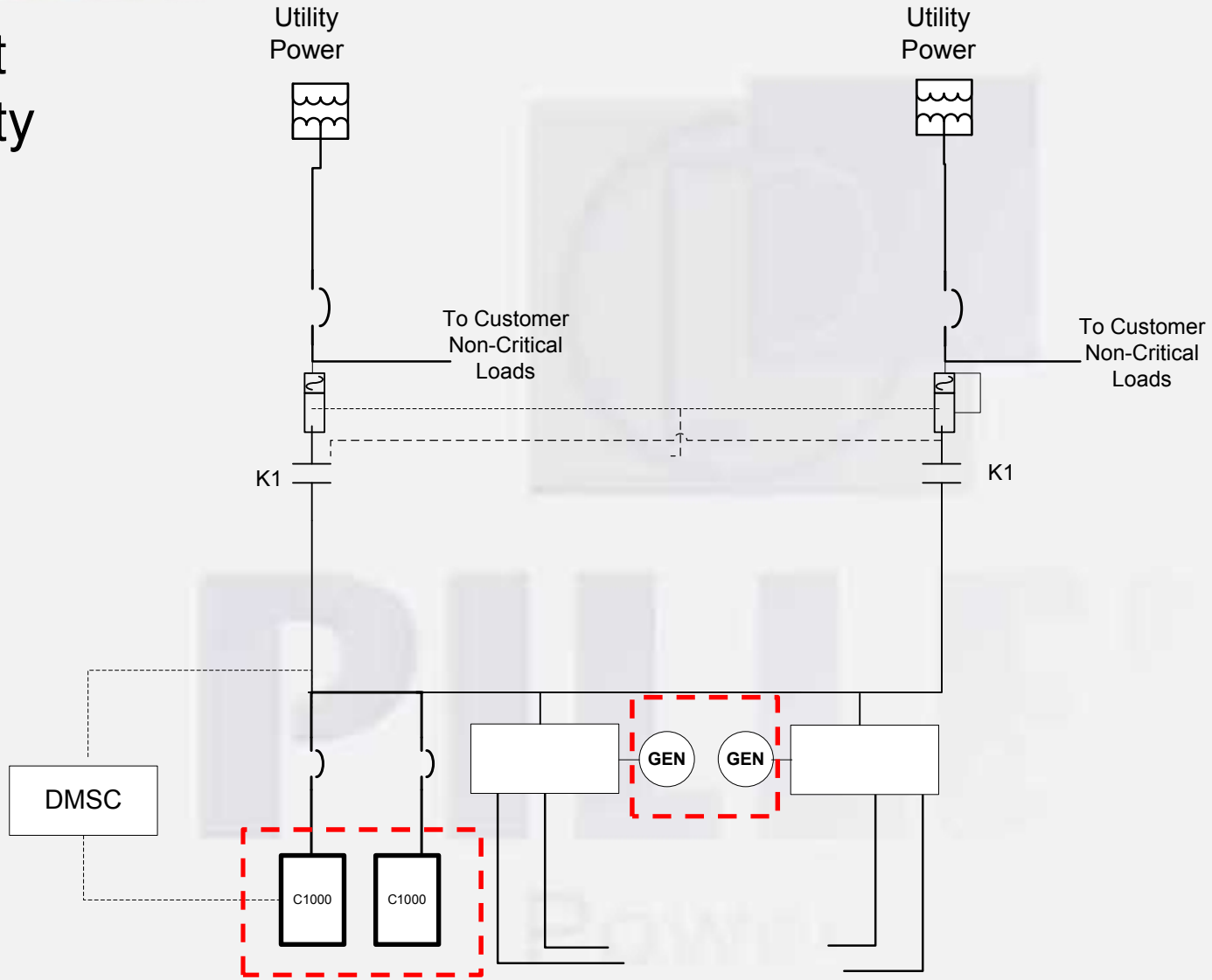
2000 kVA / 1800 KW UBT+

Original concept of an Actual System

- (2) independent 480V/60Hz utility feeds
- Utilize (2) 1MW MicroTurbines
- Utilize diesel engines

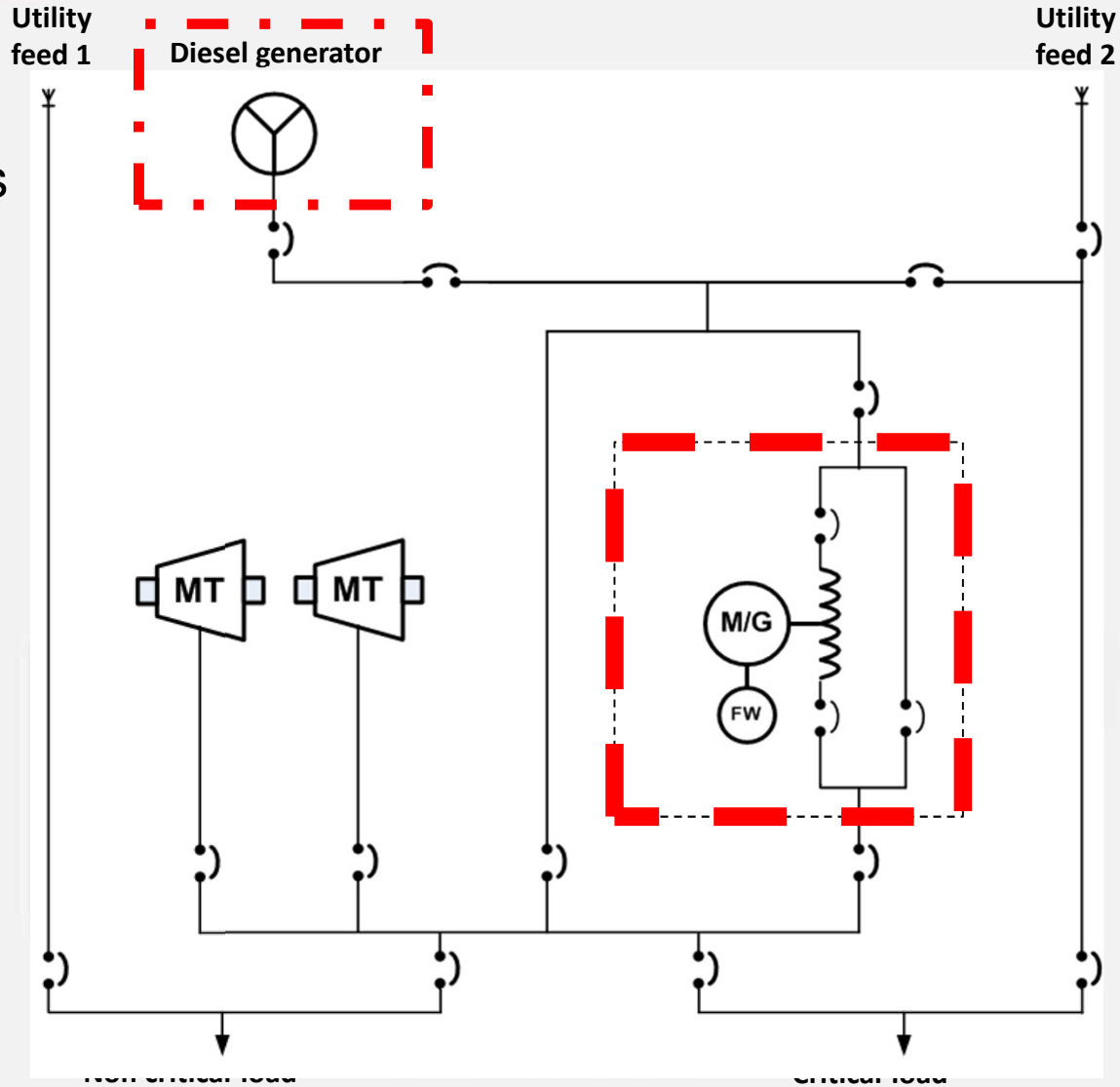
  … but …

- MicroTurbines require 6 to 8 seconds transition time



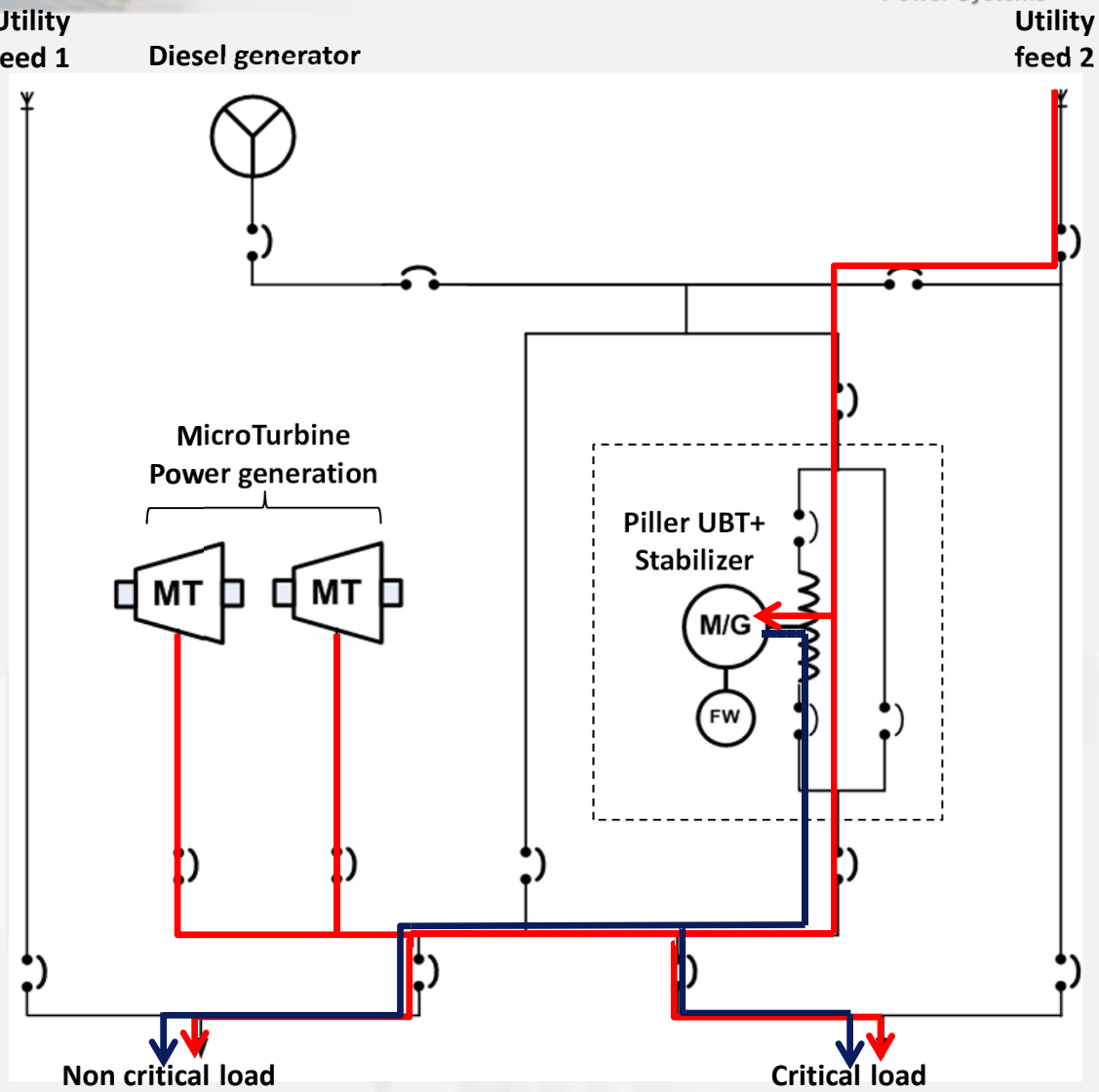
Stabilizer concept

- (2) independent 480V/60Hz utility feeds
- (2) Capstone C1000 MicroTurbine systems, each 1.0MW
- (1) Piller UBT+1800 1.8MW stabilizer with 21MJ PowerBridge
- (1) 1.25MW diesel generator



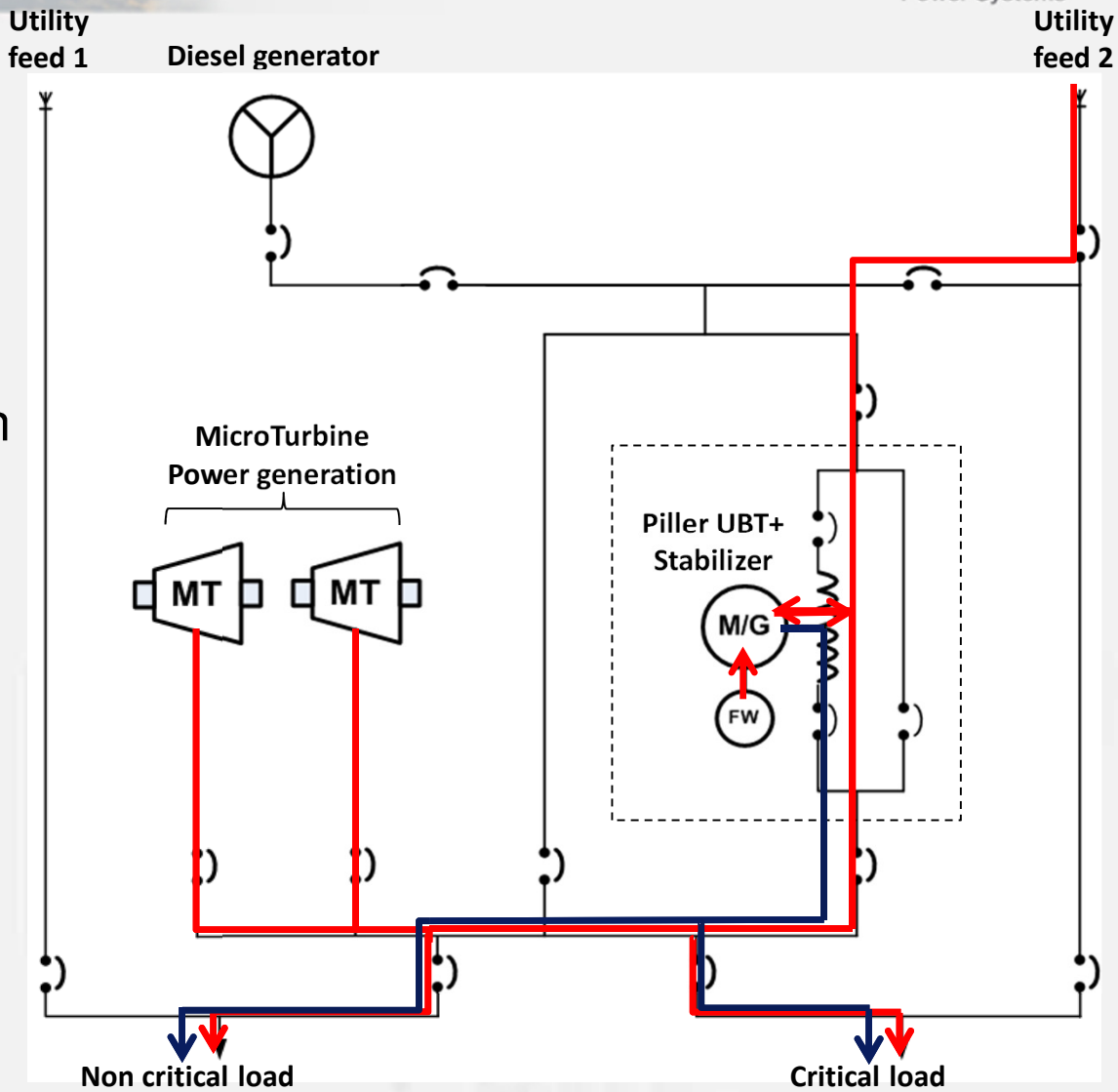
System utility mode

- MicroTurbines produce up to 1.9MW power
- Stabilizer provides reactive power
- Diesel generator is offline
- Stabilizer can supplement (import) up to 1.8MW of power
- System power ratings are
  - 1.9MW, PF0.85 with min. import
  - 3.7MW, PF0.95 with max. import



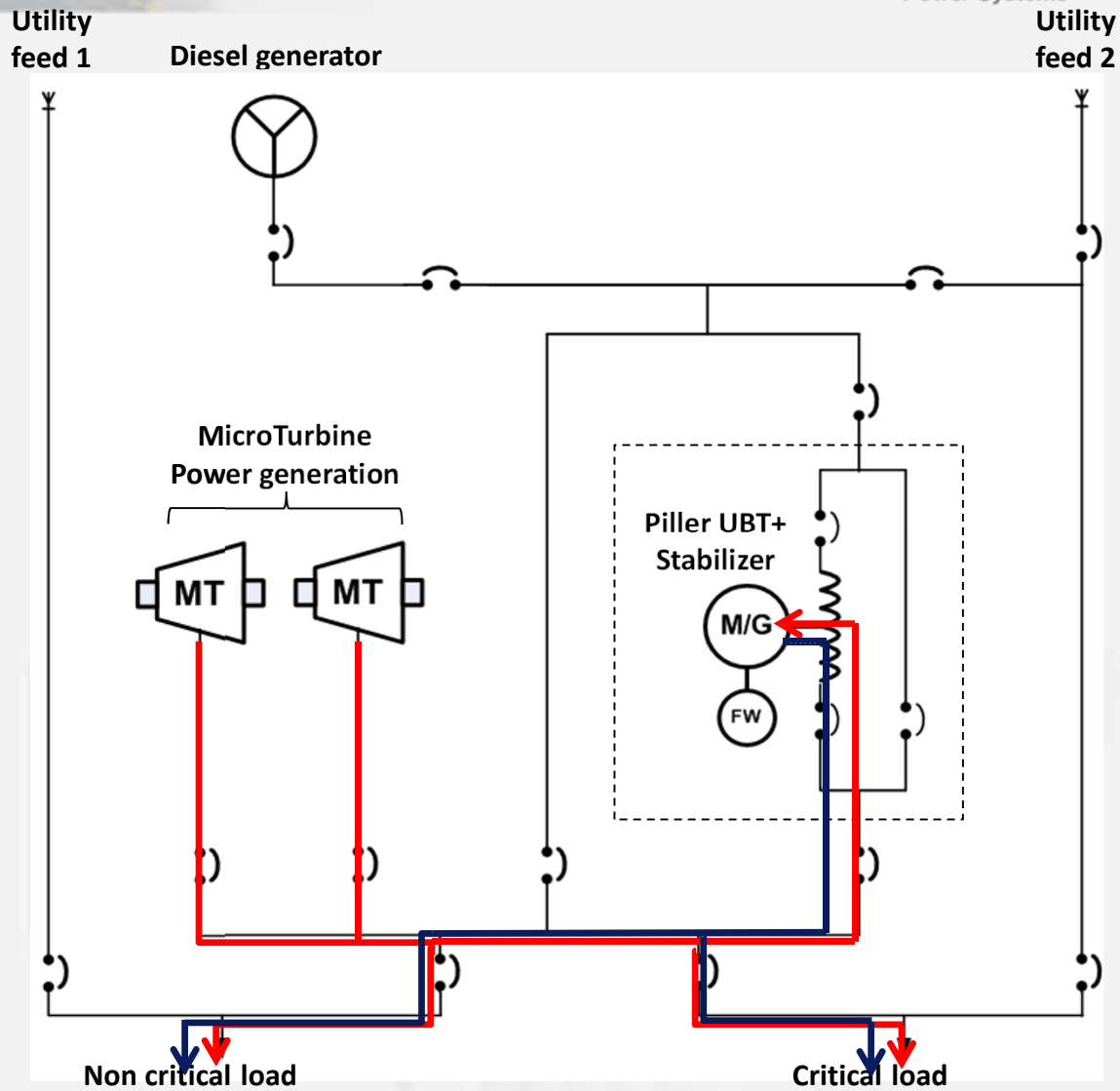
Mains failure

- Bus voltage and frequency established by UBT+ stabilizer
- MicroTurbines do not experience a change in grid voltage quality
- Change of operating mode from grid connected to island mode is not required
- No 6-8 seconds interruption



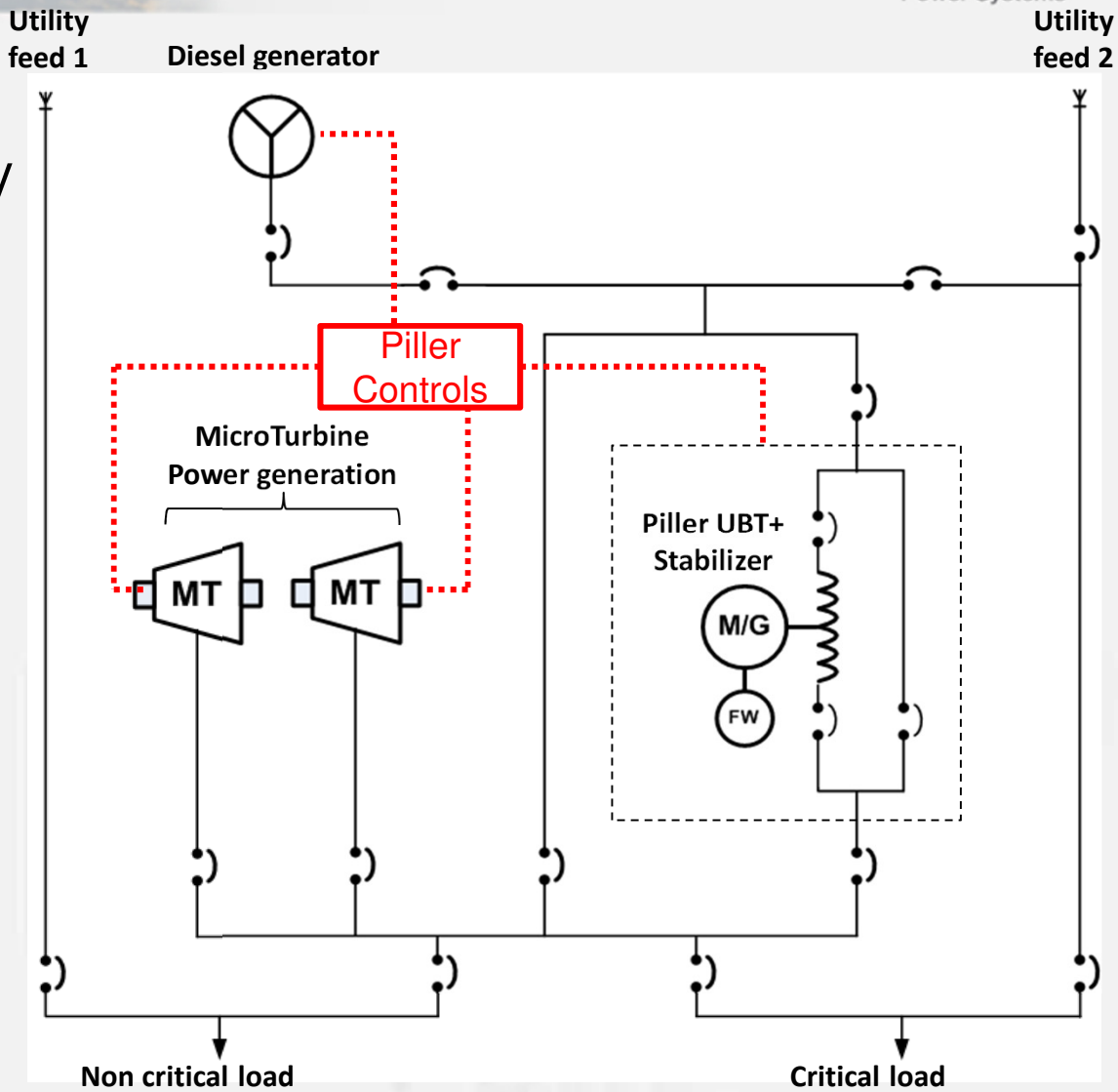
System island mode

- MicroTurbines produce up to 1.9MW power
- Stabilizer provides reactive power and requires less than 100kW parasitic losses
- Diesel generator is offline
- No additional power from utility available
- System power rating is 1.8MW, PF0.85
- Diesel generator can be brought online to supply an additional 1.25MW
- Total load capacity of 3.05MW



Stabilizer controls

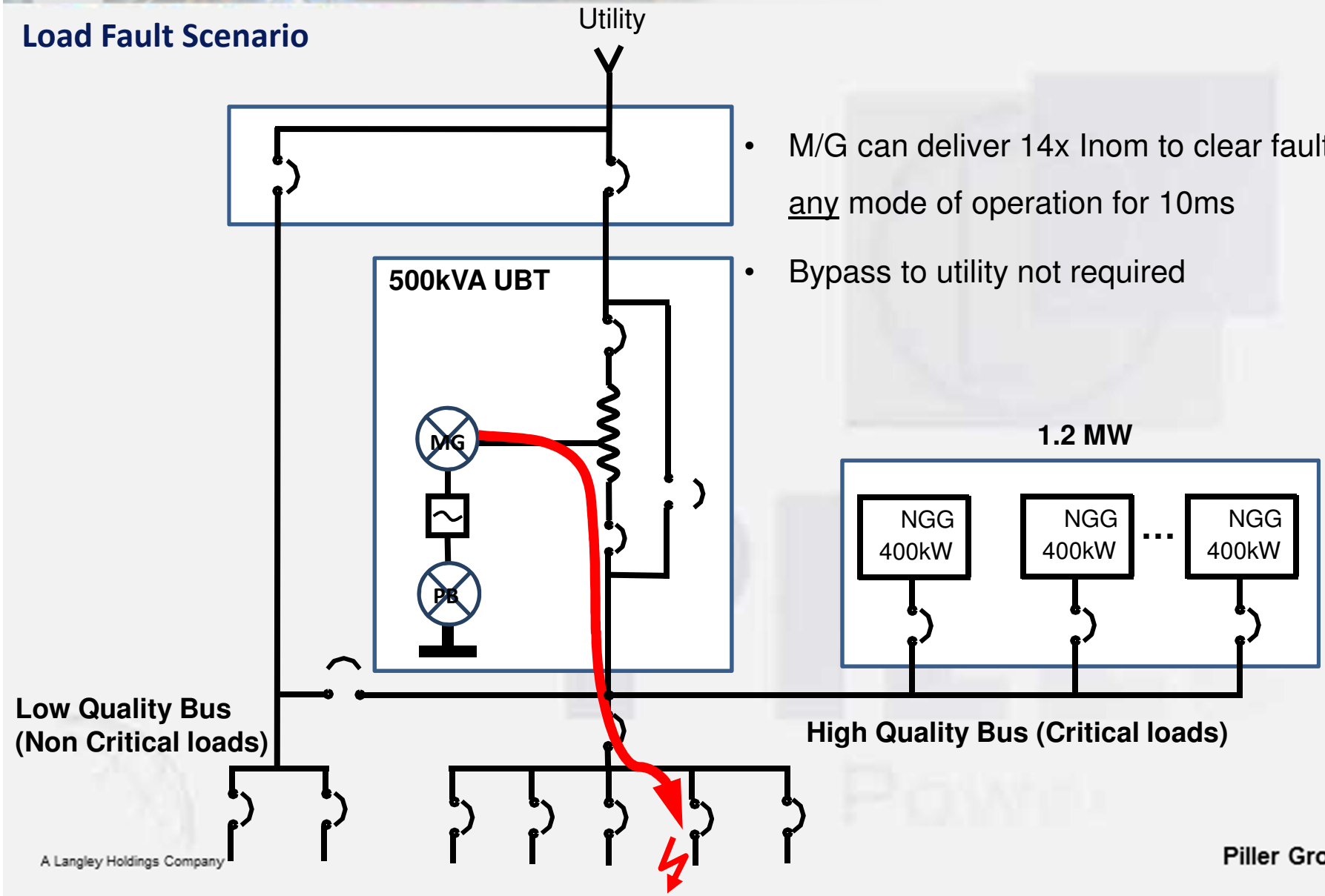
- Power demand and changes determined by UBT+ stabilizer
- Regulator in Piller Controls
- Regulator adjusts MicroTurbine output power as needed
- Additional separate regulator for diesel generator



Cogeneration Solutions
Piller UBT with Natural Gas Generators

PILLER Power Systems

Load Fault Scenario

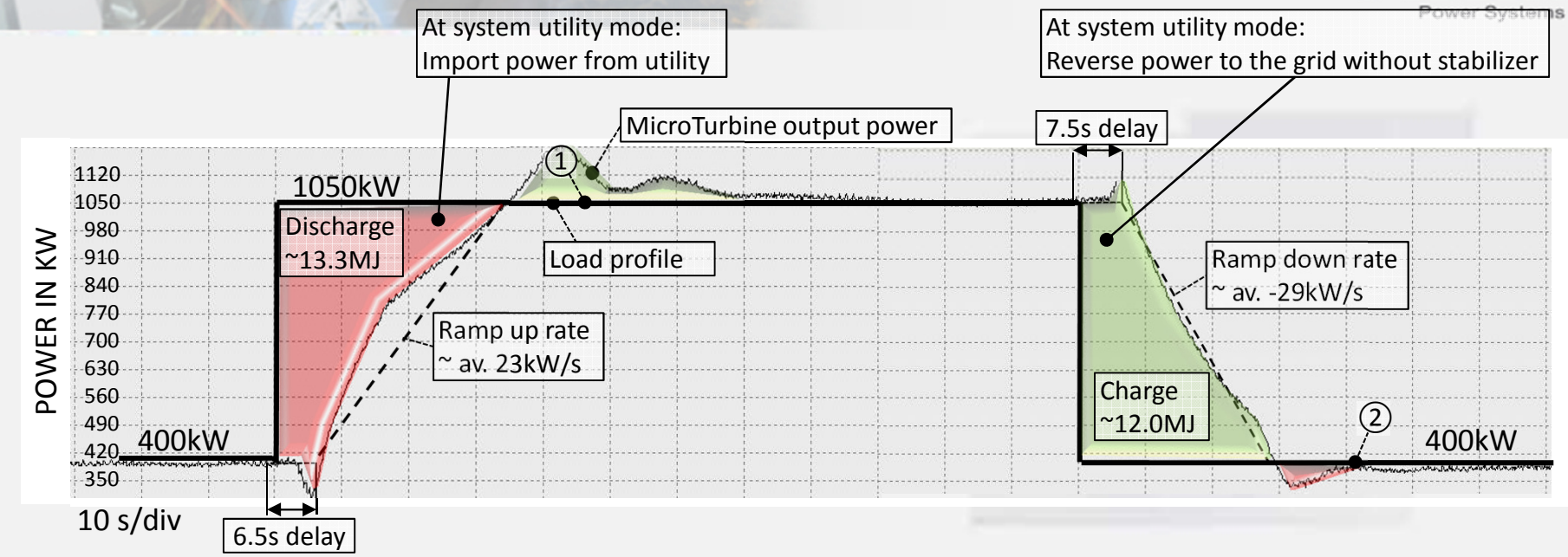


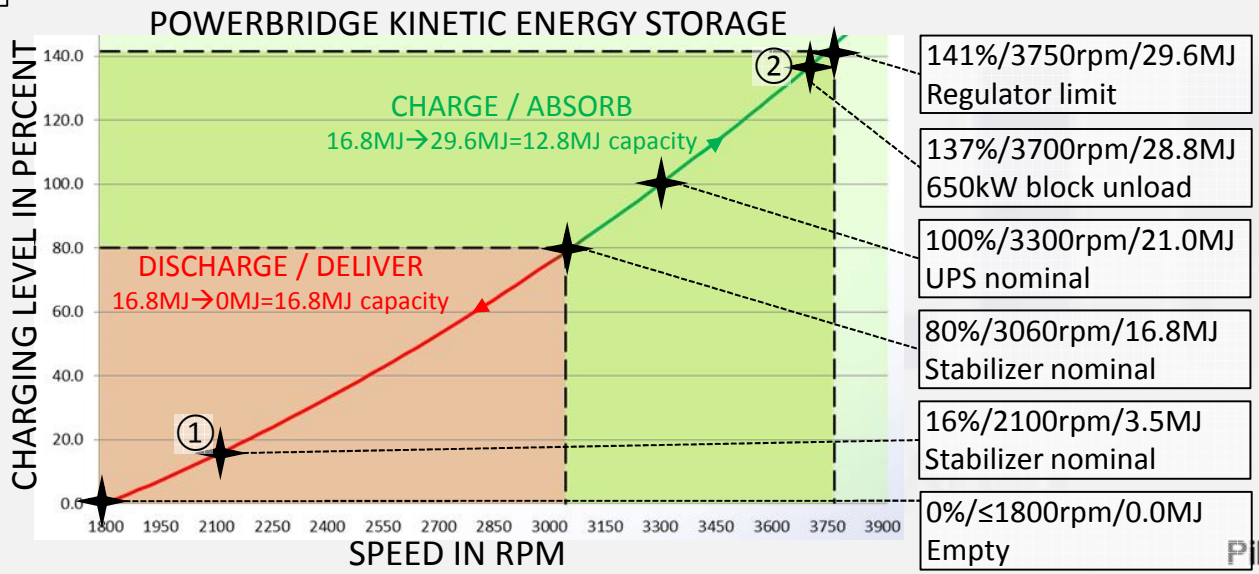
- M/G can deliver 14x Inom to clear fault in <u>any</u> mode of operation for 10ms
- Bypass to utility not required

How Big is the UPS?

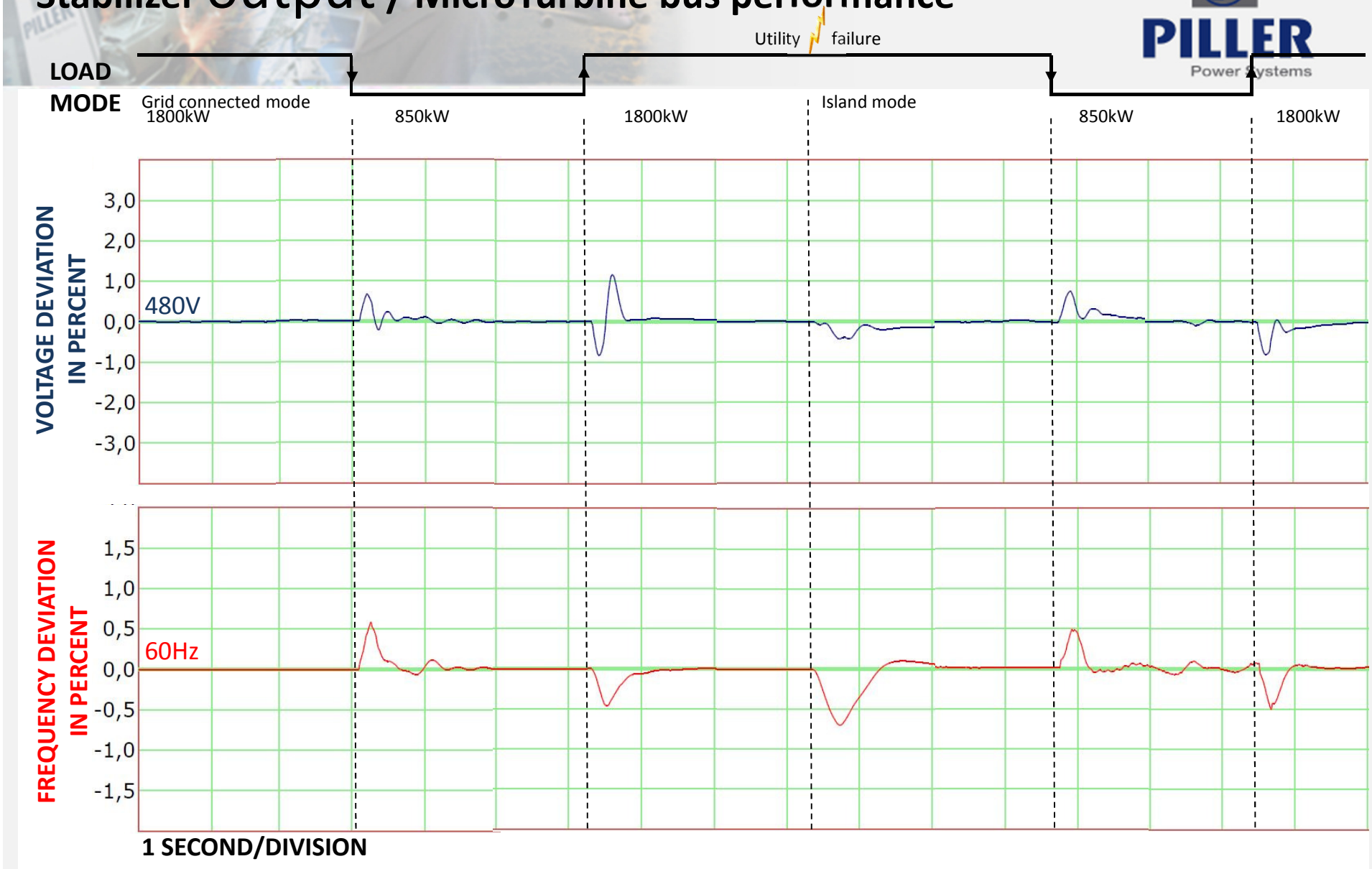
- Depends on multiple factors
  - How big are the step loads ?
  - How much fault current must be supplied ?
  - How much energy to be imported / exported ?
  - Easily calculated

Block loading & unloading on MicroTurbine system





Stabilizer output / MicroTurbine bus performance



Conclusion

- Mission Critical can mean far more than just computer systems!
- Utilizing a properly sized Rotary UPS can fully complement the dynamic performance of Natural Gas fired Co-Generation Plants, expanding the range of applications where the economic advantages of CHP are apparent.
- Co-Generation with a Rotary UPS can save money both by insulating the mission from power quality issues and by taking advantage of the efficiencies of CHP, CCHP, Tri-Generation etc.
- Distributed Generation and Demand Reduction strategies are both expanded!