Stabilized Cogeneration

Bud Leavell – Piller USA Inc.
WHY?

• Coming Grid Instability!

• Worst prognosis is Texas

• Nationally, it is coming as well
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*Below NERC Reference Margin Level*
Growing Grid Instability
Significant US Grid Weather-Related Grid Disturbances
Growing Grid Instability

Major Disturbances and Unusual Occurrences
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
Costs tend to be driven by the frequency rather than the duration of reliability events.
One Possible Solution: Co-Generation

- Grid
- Wind farms
- Loads
- Gas-/Diesel engines, turbines, etc.
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!
Issues Related to Co-Generation

• Machinery means STEP LOADS!
• Machinery means Power Factor issues.
\[ P = EI\sqrt{3}\cos\theta \]
\[ S = EI\sqrt{3} \]
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

At system utility mode:
Import power from utility

At system utility mode:
Reverse power to the grid without stabilizer

Load profile

MicroTurbine output power

1050 kW

Ramp up rate ~ av. 23 kW/s

Ramp down rate ~ av. -29 kW/s

7.5 s delay

6.5 s delay

400 kW

10 s/div

400 kW

1050 kW

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
  – 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

- Natural Gas engines,
- turbines, Fuel Cells etc.
- Wind farms
- Grid
- Rotary UPS
  with Bi-Directional
  Kinetic Energy Store
- Loads
- 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 \((\text{absorbs VARs})\)
  - over-excitation = capacitive \((\text{source of VARs})\)
- When driven mechanically with excitation becomes a generator.
Evolution of the Motor Generator
Piller UNIBLOCK
Motor Generator

Unique and highly reliable system including motor and generator

Hybrid machine developed by PILLER
UniBlock
System fan

Brushless excitation

Motor and generator windings in a common stator

Common rotor with damper winding

Pony motor
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 to 14X) 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

- 16.5 MJ 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
Utility Grid

Micro-Grid

PowerBridge

FLYWHEEL

Power Movement

EMERGENCY BYPASS

ISOLATING CHOKE

COUPLING CHOKE

Bidirectional

Power Electronics

UniBlock

MOTOR-GENERATOR

GENERATOR

MOTOR

D.C. LINK

RECTIFIER

INVERTER

A Langley Holdings Company

Piller Group
The UNIBLOCK UBT With PowerBridge
Kinetic Flywheel Energy Store

2000 kVA / 1800 KW UBT+
- (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
- 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, PF 0.85
- 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
Load Fault Scenario

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

Cogeneration Solutions
Piller UBT with Natural Gas Generators

A Langley Holdings Company
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

- **Powerbridge Kinetic Energy Storage**
- **Charging Level in Percent**
- **Speed in RPM**
- **Power IN KW**: 400kW, 1050kW
- **Load profile**: Ramp up rate ~ av. 23kW/s, Ramp down rate ~ av. -29kW/s
- **Microturbine output power**: 10 s/div
- **Charge / Absorb**: 16.8MJ, 12.8MJ capacity
- **Discharge / Deliver**: 16.8MJ, 16.8MJ capacity
- **Regulator limit**: 141%/3750rpm/29.6MJ
- **Stabilizer nominal**: 80%/3060rpm/16.8MJ
- **System utility mode**: Import power from utility, Reverse power to the grid without stabilizer
- **6.5s delay**
- **7.5s delay**

**Graphical Indications**:
- **At system utility mode**: Import power from utility
- **Reverse power to the grid without stabilizer**
- **141%/3750rpm/29.6MJ Regulator limit**
- **137%/3700rpm/28.8MJ 650kW block unload**
- **100%/3300rpm/21.0MJ UPS nominal**
- **80%/3060rpm/16.8MJ Stabilizer nominal**
- **16%/2100rpm/3.5MJ Stabilizer nominal**
- **0%/≤1800rpm/0.0MJ Empty**

**Diagram Details**:
- **1. Charge ~12.0MJ**
- **2. Discharge ~13.3MJ**

**Powerbridge Charge / Absorb Levels**:
- **16.8MJ**
- **29.6MJ**
- **21.0MJ**
- **0MJ**

**Speed Ranges**:
- **1000 to 3900 RPM**
- **10 s/div**
Stabilizer Output / MicroTurbine bus performance

LOAD MODE

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<th>1800kW</th>
<th>Island mode</th>
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<td>Island mode</td>
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<td>failure</td>
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VOLTAGE DEVIATION IN PERCENT

Frequency Deviation IN PERCENT

1 SECOND/DIVISION

480V

60Hz
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!