Best Practices, Benefits and Economics of Load Testing

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ComRent International

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Agenda

- **Introduction**
  - Overview of Load Bank Testing
- **Benefits and Economics of Load Testing**
- **Industry Trends**
  - IEEE Standards for Interconnection
  - FERC Small Generator Interconnection
- **Innovations in Load Testing**
- **Lessons Learned**

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Overview of Load Bank Testing

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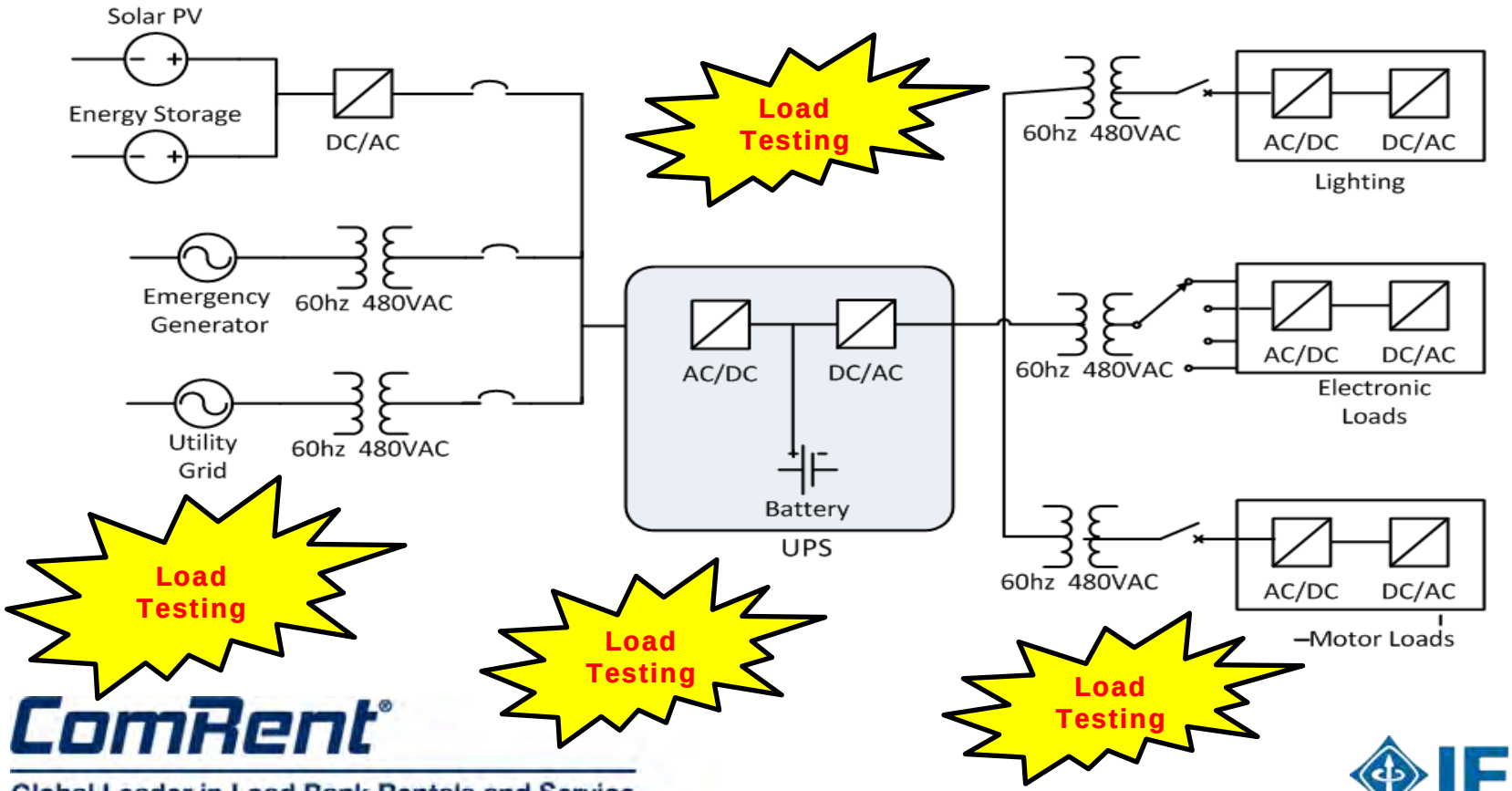
Overview of Load Bank Testing

- Load testing is done at multiple locations within a data center



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Overview of Load Bank Testing

Load Banks: Generating Success

- The load testing goal in critical facilities is to balance the electrical and thermal loads
  - We have to check the **electrical systems functionality** AND the **HVAC system's performance** in keeping the center cool.
  - Every component and connections are tested in advance

Overview of Load Bank Testing

Commissioning tests ensure equipment is rated, specified and installed properly	• Performs as system designer intended
Regular load testing ensures proper operation of equipment	• Allows failure prediction to occur during the test, and not during an unintended outage
Over time, as systems become more complex	• System test calibration ensures operation at all levels • Future standards may recommend actual load testing to ensure performance and safety
Corrective Action Validation	• Load Testing Ensures validation or verification of corrective actions to failures in the facility • Electric power system

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Benefits and Economics of Load Testing

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What to Test - Facility Uptime Tiers

Tier I – Basic Non-Redundant

- No redundancy
- Susceptible to
- Equipment configurations minimum required for equipment to operate
- Operation errors or failures will cause an interruption in service

Tier II – Basic Redundant

- Limited backup and redundancy
- Susceptible to disruptions from planned and unplanned activities
- May contain limited critical functions that can be shut down properly without adverse effects on business
- UPS and/or generator backup may be installed for parts of the building
- Failures may cause a disruption in facility service

Tier III – Concurrently Maintainable

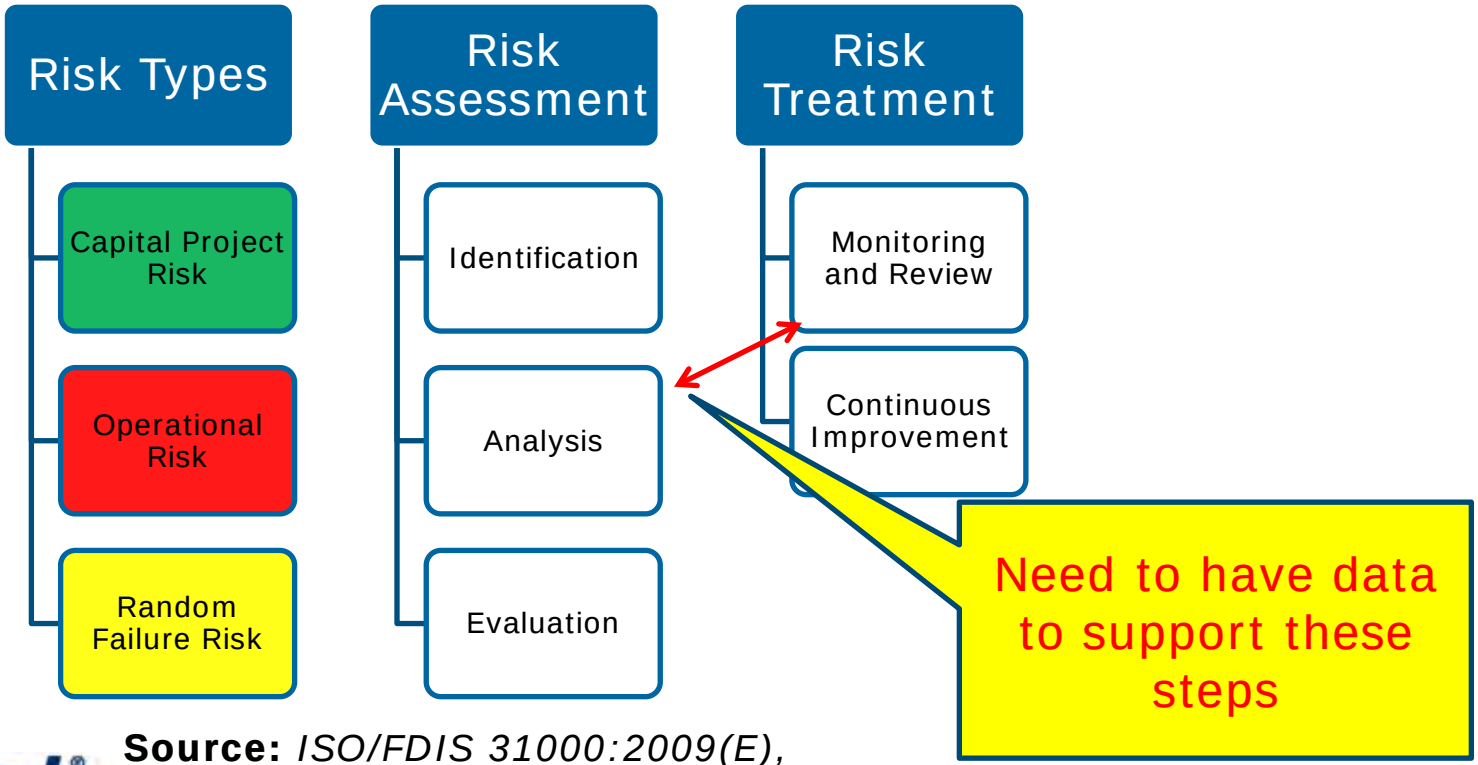
- Full single system backup and redundancy (N + I)
- Planned preventative and programmable maintenance activities, repairs, testing, etc. can be conducted without interruption of service
- Errors in operation or spontaneous failures of infrastructure may cause disruption of power to the loads

Tier IV – Fault Tolerant and Failure Tolerant

- Facility functions cannot tolerate any downtime
- No single points of failure, and multiple system backup with automated recovery (2N)
- Capable of withstanding one or more component failures, errors, or other events without disrupting power to the load
- Full load can be supported on one path without disruption while maintenance/testing is performed on the other

Benefits of Load Bank Testing

- Data Center power system is a critical investment in total system reliability aimed at reducing business risk



Source: *ISO/FDIS 31000:2009(E), pages VII and 9.*

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Benefits of Load Bank Testing in Critical Power Systems

- **Reduce Risk, Improved Reliability**
  - Probability and frequency of failures (MTBF)
- **Improved Availability**
  - Availability is defined as the percentage of time that a system is available to perform its function(s)

Availability	Hours of Downtime* (*Based on a year of 8760 hours)
0.9	876
0.999	8.76
0.99999	0.0876
0.9999999	0.000876

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Benefits of Load Bank Testing in Critical Power Systems

- **Validation of System Performance to Specification**
  - Systems need to perform at rated power with underlying assumptions
    - *Power Factor*
    - *Altitude and climate*
- **Lower Maintenance Costs**
  - Running an engine with minimal load causes residual fuel buildup.
    - *Decreases the efficiency of the engine and reduces the useful life of critical parts.*
  - As a system evolves with updated software, firmware and replacement hardware
    - *Systems need to be periodically calibrated*
- **Reduced Business Risk**
  - Damage to Reputation
  - Brand Impact

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Benefits of Load Bank Testing in Critical Power Systems

- **Reduced Business Risk**
- **60% of Data Center Failures Could be Prevented/Deferred through load testing.**

Average total cost by root causes of the unplanned outage.

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Benefits of Load Bank Testing in Critical Power Systems (Cont'd)

- **Uncover Random Failure Problems not diagnosed by sub system**

Generator Start	ATS	Circuit Breaker	UPS	Communi-cations
Generator calibration for altitude and temperature	Return to Normal Time Delay	Faulty Trip due to inrush	UPS Switches to battery power when Gens. Run	Time delay and control options need tweaking
Low cranking amps	Faulty time delay relay	Ground Fault Relay sensor imbalance	Out of tolerance battery string	Upgraded control firmware incompatibility

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Benefits of Load Bank Testing in Critical Power Systems (Cont'd)

- A well run full load test can **Reduce Project Costs**
  - Faster setup, testing and takedown
    - Reduced overall time for commissioning test (days)
    - Reduced load bank setup time (hours)
    - Less checking and reworking of connections by Installer Faster set up of downstream tests with buss track adapters and rack mounted load banks
    - Less changeover when switching tests to multiple service providers
- Reduced labor from stakeholders involved in commissioning
  - Generator, UPS Mfr.
  - General Contractor, Electrical Contractor
  - Consulting Engineer
  - Facilities Owner/Manager

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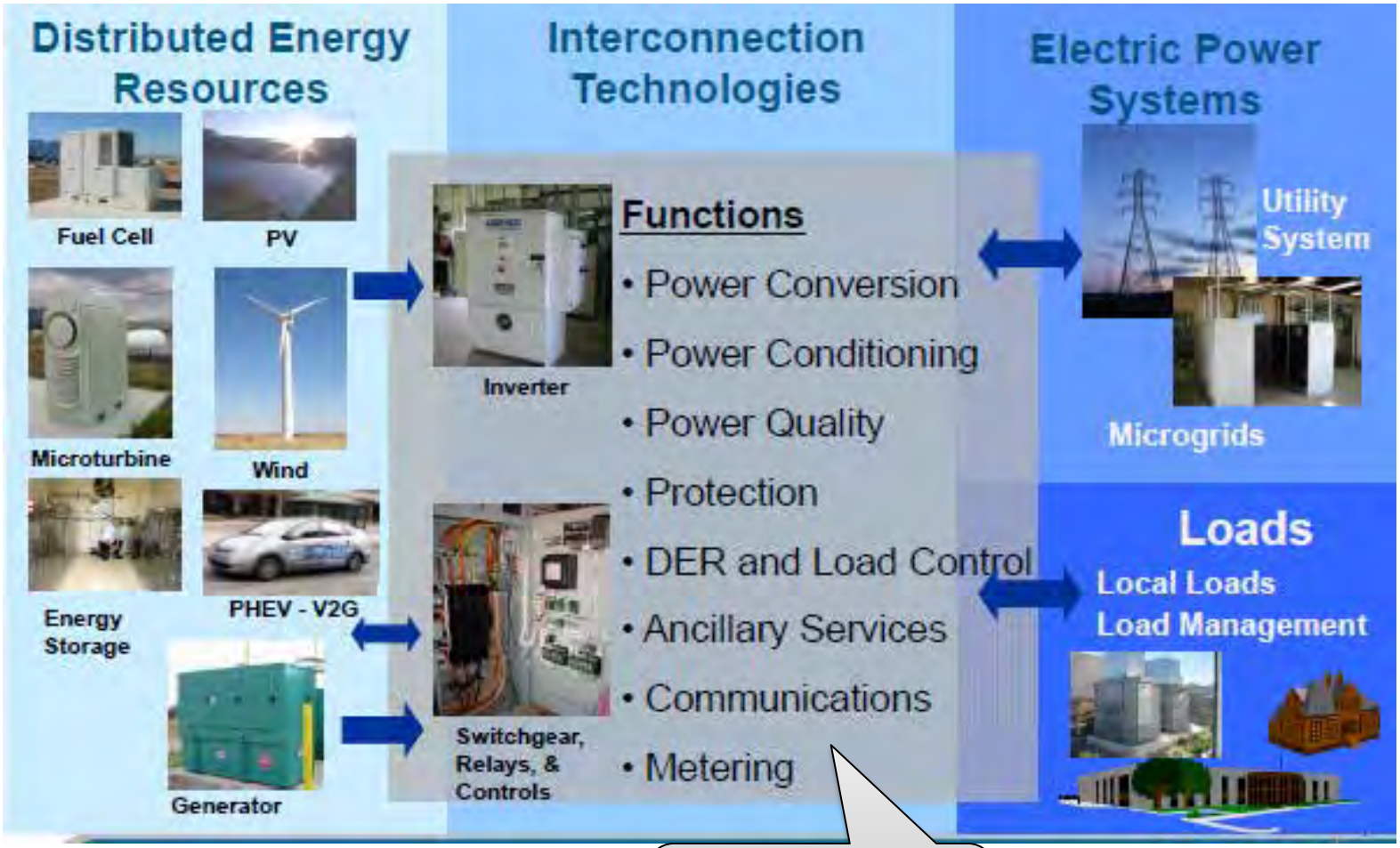
Benefits of Load Bank Testing in Utility Substations (Cont'd)

- Substations on new circuits or that are great distance from active feeders can benefit from load bank testing during commissioning
  - Energize circuit with sufficient current to allow CT's to test protective relay settings and operation
  - Also test communication systems
- Utility ratemaking process can allow this expense to be capitalized

Industry Trends

Industry Trends

Distributed Energy Resource Interconnection



SCC 21 Coordination

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Industry Trends
Distributed Energy Resource Interconnection

Standards

- IEEE 1547-2003 Standard for Interconnecting Distributed Resources to the EPS
  - Today, IEEE1547-2003 Restricts Voltage, Frequency Regulation or Power Factor Correction at the PCC
  - Wording added to allow Voltage, Frequency Regulation (by injecting reactive Power) and Power Factor Correction in collaboration with EPS operator. If disputes arise, a full load test may be required to resolve technical differences.
- P1547.5 Interconnection of Electric Power Sources Greater than 10MVA to the Power Transmission Grid (Wind Farms)
  - IEEE1547.5 was withdrawn by IEEE in 2011 due to lack of Progress. IEEE wants to reinitiate this due to continued problems encountered when commissioning these systems.
  - Objective will be to reinstate this WG and institute the common practice for commissioning wind farms.

Key:
- **Current Situation**
- **Probable 2013 Activity**

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Industry Trends
Distributed Energy Resource Interconnection

"Small" Generator Project Approval Rules

- FERC Proposed Reforms for Small Generator Interconnection [Docket No. RM13-2-000]
  1. Allow customers to request a pre-application report to evaluate opportunity. **No review exists today.**
  2. Revise **2 MW** threshold for participation in the Fast Track Process (FTP) **increased to** a limit of **5 MW**
  3. Revise the customer options supplemental review for projects that fail FTP criteria. **No feedback or follow-up allowed.**
  4. FERC's pro forma Small Generator Interconnection Procedures (SGIP) revised to allow customers an opportunity to provide written comments on the upgrades that are necessary for the interconnection **(transmission provider has total say)**

Key:
- **Current Situation**
- **Probable 2013 Activity**

Industry Trends
Smart Grid Interoperability of DR with EPS

Smart Grid Interoperability

- IEEE P2030.2 - Guide for the Interoperability of Energy Storage Systems
  - First standard using the IEEE 2030 Smart Grid Interoperability model. I am Working Group Chair
  - Writing Committees Engaged to produce a ballot able draft by end of 2013.

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Key:
- **Current Situation**
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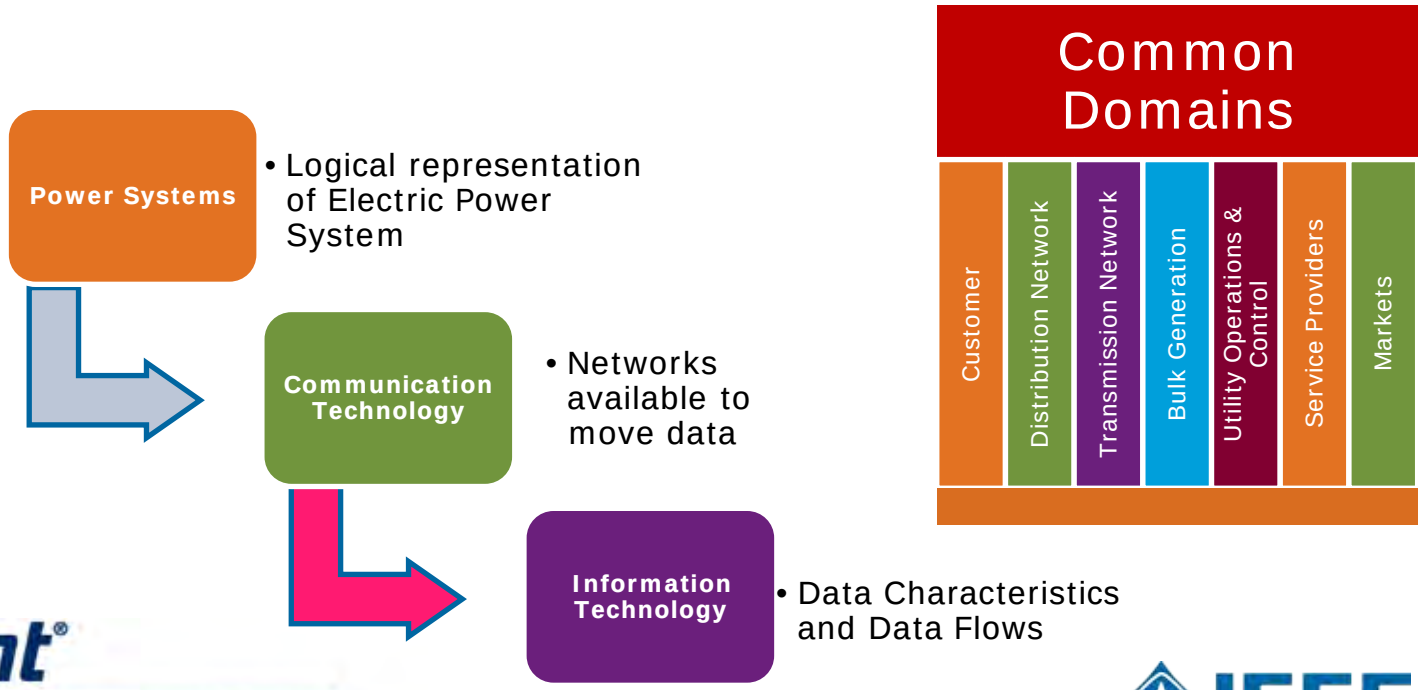
Industry Trends
Smart Grid Interoperability of DR with

- **IEEE 2030-2011 - Guide for Smart Grid Interoperability**
  - More commonality and completeness in communications and information technology requirements



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Industry Trends
Special Standards

- Special Cases
  - UL Standards Technical Panel 1741 (Inverters and Converters)
    - Type Testing Standard for Inverters and Converters
    - Revision due in 2013
  - UL Standards Technical Panel - UL 6171 – Standard for Wind Turbine Converters and Interconnection Systems Equipment (Startup in late 2013)
    - No standards exist today.
    - Clarity on interconnection and load testing requirements.

Key:
- **Current Situation**
- **Probable 2013 Activity**

Load Testing Best Practices

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Load Testing Best Practices

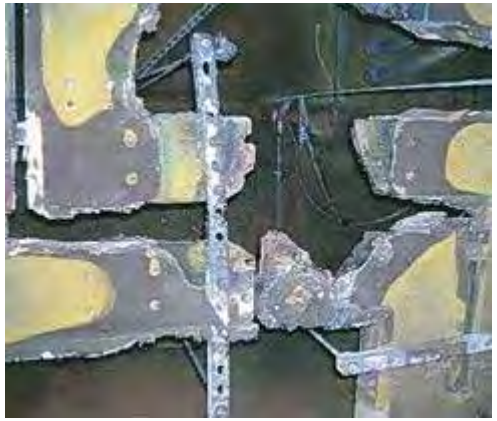
- Load testing at commissioning and maintenance intervals reduce the incidence of catastrophic failures.

Load Testing Best Practices

Arc Flash Explosion

Facility Damage

Circuit Breaker



Bus Bar

Load Testing Best Practices

- Data Center Integration Testing
  - THE PROBLEM:
    - Data center testing occurs months before servers are installed
    - Owners need to ensure the complex systems operate as intended.

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Load Testing Best Practices

- Power System
- Generator Individual
- Generators in Parallel
- Automatic Transfer Switch
- UPS Modules
- Power Distribution Units (PDU's)
- Remote Power Panel (RPP's)
- Overhead or under floor distribution or Bus System
- In Rack Power Strips

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Load Testing Best Practices

HVAC

Heating Ventilation Air Conditioning

- Chillers
- Cooling Towers
- CRAC Units Computer Room Air Conditioners
- Humidity controllers
- Economizers (outside air blending)

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Load Testing Best Practices

IST Integrated Systems Test

- Combines all HVAC and Power Systems and applies load to the data center as a whole.
- As the load banks produce electrical load, it is discharged as heat. The cooling system is tested, Tuned and Balanced.
- System failure modes are explored and documented.

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Load Testing Best Practices

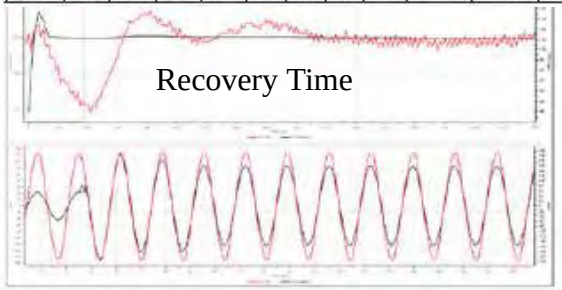
- Critical Facility Power Quality
  - THE PROBLEM
    - Power Quality Measurement requires costly, equipment that takes a high level of training to interpret results.
    - Equipment suppliers pointing fingers when problem occurs

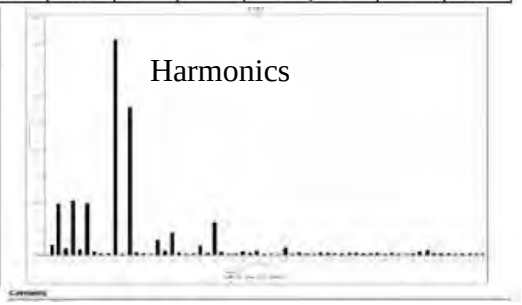
Load Testing Best Practices

- Power Quality Measurement
  - Technology can provide comprehensive results with little test time

Time	Amps				Volts				KW	Hz	PF	Water Temp.	Amb. Temp.	Exhaust Temp.	Oil Press	Batt Volts	Charge Amps	Eng Hours
	1	2	3	AVG	1-2	2-3	3-1	AVG										
8:40	180	180	180	180	481	481	481	481	150	60.0	1.0	177	50		81	27	1	283
8:45	360	361	361	361	480	481									80	27	1	283
8:50	540	541	541	541	480	481									79	27	1	283
8:55	578	577	577	577	480	481									79	27	1	284
9:00	721	721	721	721	480	481	481	481	600	60.0	1.0	180	50		79	27	1	284
9:15	721	721	721	721	480	481	481	481	600	60.0	1.0	180	50		78	27	1	284
9:30	721	721	721	721	480	481	481	481	600	60.0	1.0	179	50		79	27	0	284
9:45	721	721	721	721	480	481	481	481	600	60.0	1.0	180	50		79	27	0	285
10:00	721	721	721	721	480	481	481	481	600	60.0	1.0	180	50		79	27	0	285

Power Quality Test Report





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Load Testing Best Practices

- Medium Voltage Feeds and Emergency Generators
  - THE PROBLEM
    - Many data centers use Medium Voltage Utility Feeds and employ Medium Voltage Emergency Generators
    - Load Testing with low voltage load banks results in complicated connections, space constraints and sloppy job site appearance.

Load Testing Best Practices

Backup Power/ Grid Interconnection

- CR922A 5MW MV Load Bank: Transportable medium voltage load bank
  - No Transformer
  - CAPACITY:
    5MW @13,800 VAC
  - Easy set up
  - Linkable for larger loads
  - Reduces time & labor cost

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Load Testing Best Practices

- High Voltage Substations
  - THE PROBLEM
    - Little scheduling flexibility when commissioning substation
    - Highly constrained resources that set up and test communications and protection systems make project management difficult

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Load Testing Best Practices

- Substation Pre-Commissioning
  - Bring in partial load sufficient to energize CT's to test communications protective relays

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RECENT COMRENT PROJECTS:
CHEVRON OIL FIELD – 3 EACH 3MW SOLAR GAS TURBINES

Provided: 9 MW's Resistive / Reactive .8PF at 12470 volts

Load Testing Best Practices
SCE Wind Hub Substation

Serving renewable energy Solar and Wind Farms in Southern California- P
Provided :26 MW's of MV load (@13.8kv) Load Banks, Switch Gear and op

Load Testing Best Practices
Copper Mine, Kingman, AZ

50MW GE Natural Gas Turbine Generator
Provided: 42MW's of MV load (@13.8kv), transformers, switchgear, cables.

Load Testing Best Practices

- Critical Facility Load Testing and Commissioning
  - **THE PROBLEM**
    - Load testing can take several days at a site and requires skilled labor to be available to control load and load steps
    - Often the sites are considered unsafe while load is being energized

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Load Testing Best Practices

Wi-Fi / Enhanced Communications:

- IP addressable load banks
- Manage all load banks via a single mobile device
  - In the rack
  - In the aisle
  - In the room
- Reduces Test Time
- Reduced labor cost

Customized MS Windows GUI

Android Smartphone Interface Application

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Lessons Learned

Lessons Learned

- Load testing is a critical and beneficial aspect of building commissioning and maintenance.
- Innovations can make testing safer and faster
- Bottom line is effective power system commissioning and testing saves you project costs and reduces operating expense