Best Practices, Benefits and Economics of Load Testing

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ComRent International
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
Overview of Load Bank Testing

Load testing is done at multiple locations within a data center.
Load Bank Testing – Utility Scale

- Partial Load Testing

Apply enough load so Current Sensors can operate

- Allows testing of protective relays and communications
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

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

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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

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IEEE

8/1/2013
Benefits of Load Bank Testing

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

Risk Types
- Capital Project Risk
- Operational Risk
- Random Failure Risk

Risk Assessment
- Identification
- Analysis
- Evaluation

Risk Treatment
- Monitoring and Review
- Continuous Improvement

Need to have data to support these steps

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)

<table>
<thead>
<tr>
<th>Availability</th>
<th>Hours of Downtime* (*Based on a year of 8760 hours)</th>
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<tbody>
<tr>
<td>0.9</td>
<td>876</td>
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<tr>
<td>0.999</td>
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<td>0.9999999</td>
<td>0.000876</td>
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</table>

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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.**

![Bar Chart: Average total cost by root causes of the unplanned outage.]

- IT equipment failure: $750,326
- UPS system failure (battery): $687,700
- Other root causes: $612,993
- Water, heat or CRAC failure: $489,100
- Generator failure: $463,890
- Weather related: $395,065
- Accidental/human error: $298,099

Average total cost by root causes of the unplanned outage.
### Benefits of Load Bank Testing in Critical Power Systems (Cont’d)

Uncover Random Failure Problems not diagnosed by sub system

<table>
<thead>
<tr>
<th>Generators Start</th>
<th>ATS</th>
<th>Circuit Breaker</th>
<th>UPS</th>
<th>Communications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generator calibration for altitude and temperature</td>
<td>Return to Normal Time Delay</td>
<td>Faulty Trip due to inrush</td>
<td>UPS Switches to battery power when Gens. Run</td>
<td>Time delay and control options need tweaking</td>
</tr>
<tr>
<td>Low cranking amps</td>
<td>Faulty time delay relay</td>
<td>Ground Fault Relay sensor imbalance</td>
<td>Out of tolerance battery string</td>
<td>Upgraded control firmware incompatibility</td>
</tr>
</tbody>
</table>
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 setup 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
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
Distributed Energy Resource Interconnection

Distributed Energy Resources
- Fuel Cell
- PV
- Microturbine
- Wind
- Energy Storage
- PHEV - V2G
- Generator

Interconnection Technologies
- Inverter
- Switchgear, Relays, & Controls
- Metering
- Power Conversion
- Power Conditioning
- Power Quality
- Protection
- DER and Load Control
- Ancillary Services
- Communications

Electric Power Systems
- Utility System
- Microgrids

Loads
- Local Loads
- Load Management

SCC 21 Coordination
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
- Changes complete and in ballot draft.
  - 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 t
- Working Group initiated to develop IEEE1547.1 test procedures

Key:
- Current Situation
- Probable 2013 Activity
“Small” Generator Project Approval Rules

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**)
Smart Grid Interoperability


- First standard using the IEEE 2030 Smart Grid Interoperability model. I am Working Group Chair
- Targeting ballot by end of 2013.
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

**Common Domains**
- Customer
- Distribution Network
- Transmission Network
- Bulk Generation
- Utility Operations & Control
- Service Providers
- Markets

**Power Systems**
- Logical representation of Electric Power System

**Communication Technology**
- Networks available to move data

**Information Technology**
- Data Characteristics and Data Flows
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

  - No standards exist today.
  - Clarity on interconnection and load testing requirements.

Key:
- Current Situation
- Probable 2013 Activity
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
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.
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

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

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<th>Amps</th>
<th>Volts</th>
<th>KW</th>
<th>Hz</th>
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<th>Water Temp</th>
<th>Amb. Temp</th>
<th>Exhaust Temp</th>
<th>Oil Press</th>
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Power Quality Test Report

Recovery Time

Harmonics
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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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
Load Testing Best Practices

Substation Pre-Commissioning

- Bring in partial load sufficient to energize CT’s to test communications protective relays
RECENT COMRENT PROJECTS:
CHEVRON OIL FIELD – 3 EACH 3MW SOLAR GAS TURBINES

Provided: 9 MW’s Resistive / Reactive .8PF at 12470 volts
Serving renewable energy Solar and Wind Farms in Southern California - Provided: 26 MW’s of MV load (@13.8kv) Load Banks, Switch Gear and operators.
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.
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.
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
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.