Facility Maintenance Best Practices

Making the Most of What You Have

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About the Speaker

Jeff Womack

- Vice President & Project Executive with Hood Patterson & Dewar
- 12 years of electrical design experience
  - Commercial Electrical Design
  - Data Centers
  - MTSO Facilities
- 20 years of electrical testing, electrical commissioning experience
  - Data Center Commissioning / Integration
  - Live Site Commissioning
  - Facility Assessments
  - Failure Analysis
  - Acceptance and Maintenance Testing

Agenda

- Facility Maintenance
- NFPA 70B Recommended Practice for Electrical Equipment Maintenance
- What are Best Practices?
- Considering all the angles
- Determining the best approach
- Examples – What not to do
- Arc Flash and Other Considerations

Why Preventative Maintenance?

An Effective Program Pays Dividends

- Improves equipment lifespan
- Reduces downtime
- Helps prevent accidents, lost production, and loss of profit
- Reduces equipment failure to a minimum consistent with good economic judgement
- Success requires management support

Preventative Maintenance

How Much Do You Really Need?

- Which recommendations should you follow?
- What is a best practice?
- Where should you spend the money?

Preventative Maintenance

Basics

- A good program begins with good design
- Well qualified and properly trained individual needs to be responsible
- Maintenance Plan is very Important
- Test and analysis
- Programmed inspections
- Diagrams
- Maintenance Procedures – Do they meet the minimums and maximums?

Project Example

Telecom Provider Generator Abuse

- Generator load testing
- 100% block loading every week leads to damage of multiple alternators
- 2^{nd} Failure prompted testing of all generators

Project Example

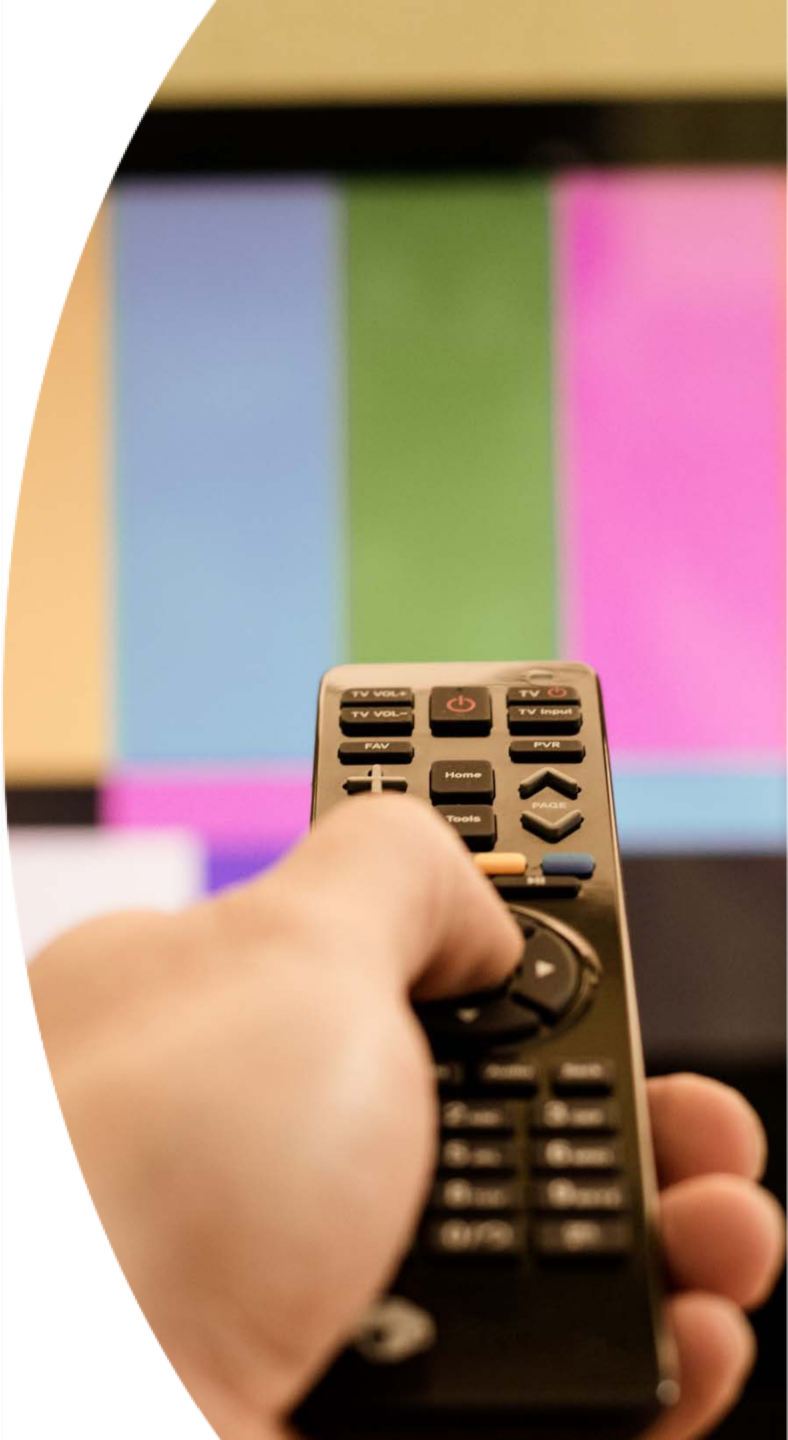
Credit Card Company has Facilities and IT disconnect

- IT equipment added
- Facilities not allowed to shut down power to verify proper A-B cording
- No coordination between departments
- UPS system failure reveals dual corded loads are connected to the same power source

Project Example

TV Service Provider Budget Freeze

- Equipment is out of date and needs upgrade
- Upper management doesn’t understand importance
- Budget gets lost in buyout
- UPS battery failure drops critical load
- Failures don’t wait for decisions to be made



Project Example

Airline Service Provider puts on Blinders

- Facility constructed in early 1990s
- Never had a utility power disruption
- Maintenance personnel have difficulty convincing management to replace obsolete UPS modules
- At the time of replacement there were not enough batteries left in the string to support an outage

NFPA 70B-2019

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NFPA 70B-2019

Recommended Practice for Electrical Equipment Maintenance

- Intended to reduce hazards to life and property that can result from failure or malfunction of electrical systems and equipment
- Explains the benefits of an Effective Electrical Preventative Maintenance (EPM) program
- Explains the function, requirements, and economic considerations used to establish and EPM program
- Not intended to replace manufacturers recommendations

NFPA 70B-2019

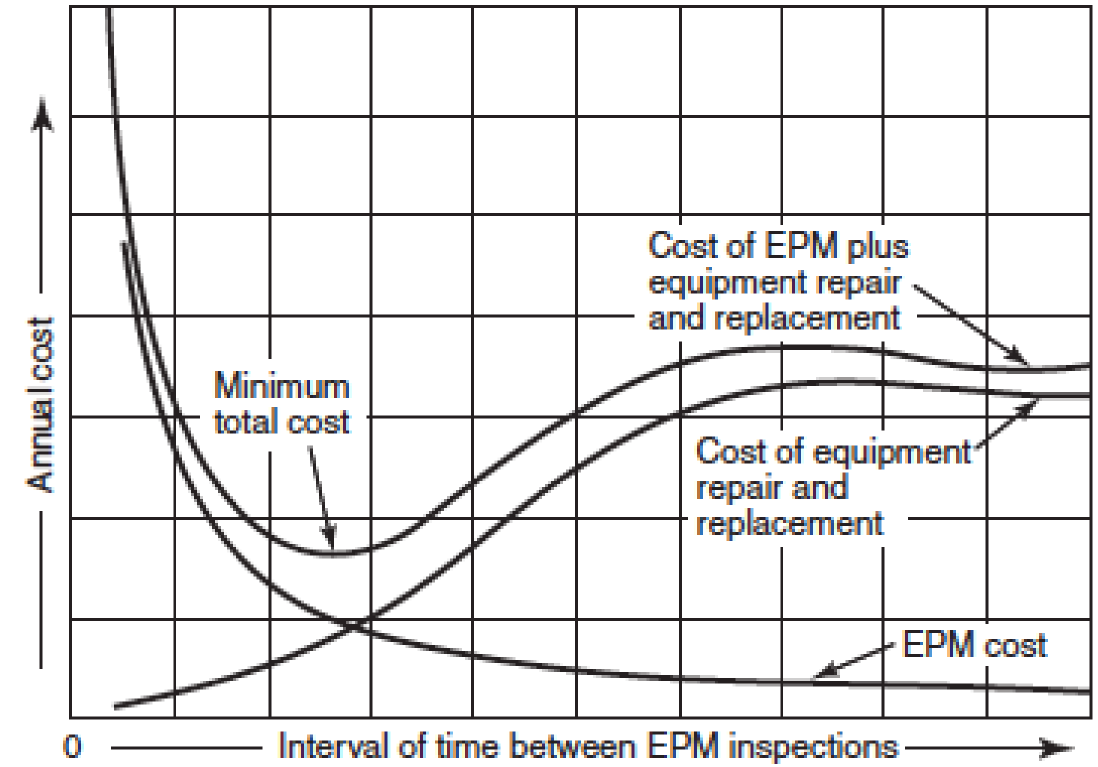
Reference Publications

- NFPA – National Fire Protection Association
- ATSM – American Society for Testing and Materials
- EASA – Electrical Apparatus Service Association
- IEEE – Institute of Electrical and Electronics Engineers
- NEMA – National Electrical Manufacturers Association
- NETA – International Electrical Testing Association
- OSHA – Occupational Safety and Health Administration
- UL – Underwriters Laboratories
- Publications from public agencies such as FEMA

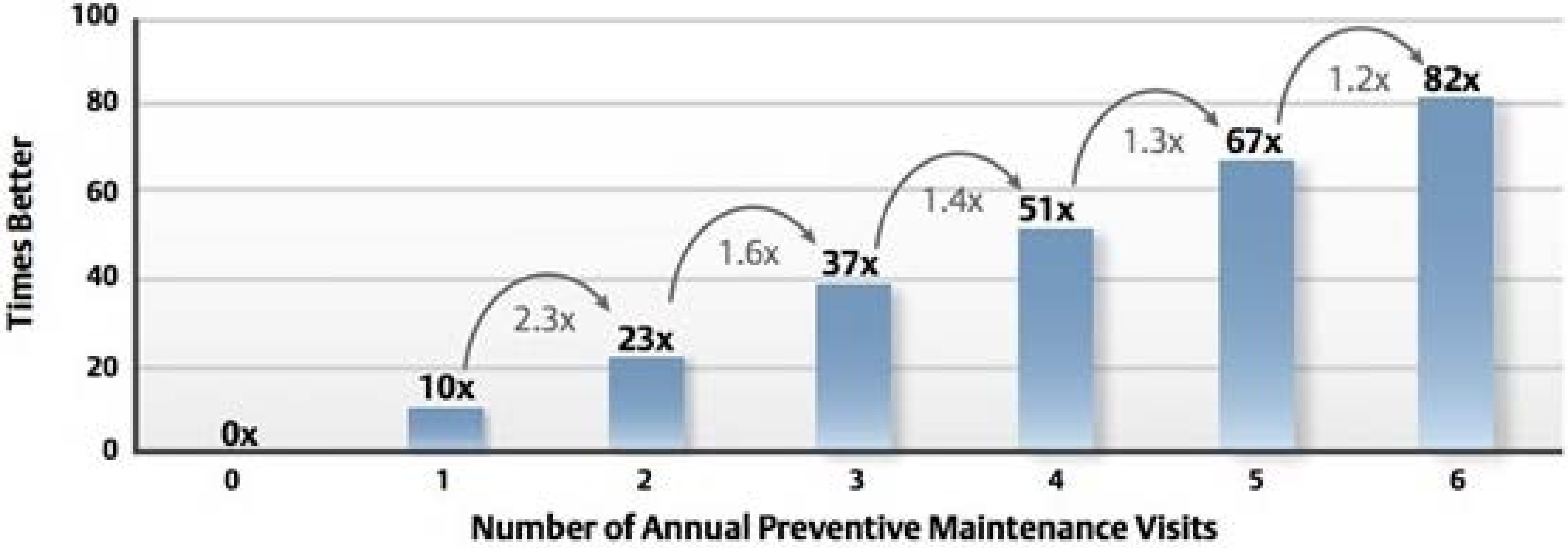
Preventative Maintenance

How often?

- Inspection Frequency
- Maintenance Frequency
- Replacement Frequency



Preventative Maintenance Frequency Impact



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NETA Tables

MAINTENANCE FREQUENCY MATRIX				
		Equipment Condition		
		Poor	Average	Good
Equipment Reliability Requirement	Low	1.0	2.0	2.5
	Medium	0.50	1.0	1.5
	High	0.25	0.50	0.75

Frequency of Maintenance Tests				
Inspections and Tests Frequency in Months (Multiply These Values by the Factor in the Maintenance Frequency Matrix)				
Section	**Description**	**Visual**	**Visual & Mechanical**	**Visual & Mechanical & Electrical**
7.1	Switchgear & Switchboard Assemblies	12	12	24
7.2	Transformers			
7.2.1.1	Small Dry-Type Transformers	2	12	36
7.2.1.2	Large Dry-Type Transformers	1	12	24

Project Example

County Jail Starts Riots

- Infrared scan never completed
- Aluminum bussing in switchgear start phase to phase “busicle”
- Arc between phases clears the “busicle”
- B phase voltage goes from 277 to 42 due to bad connection

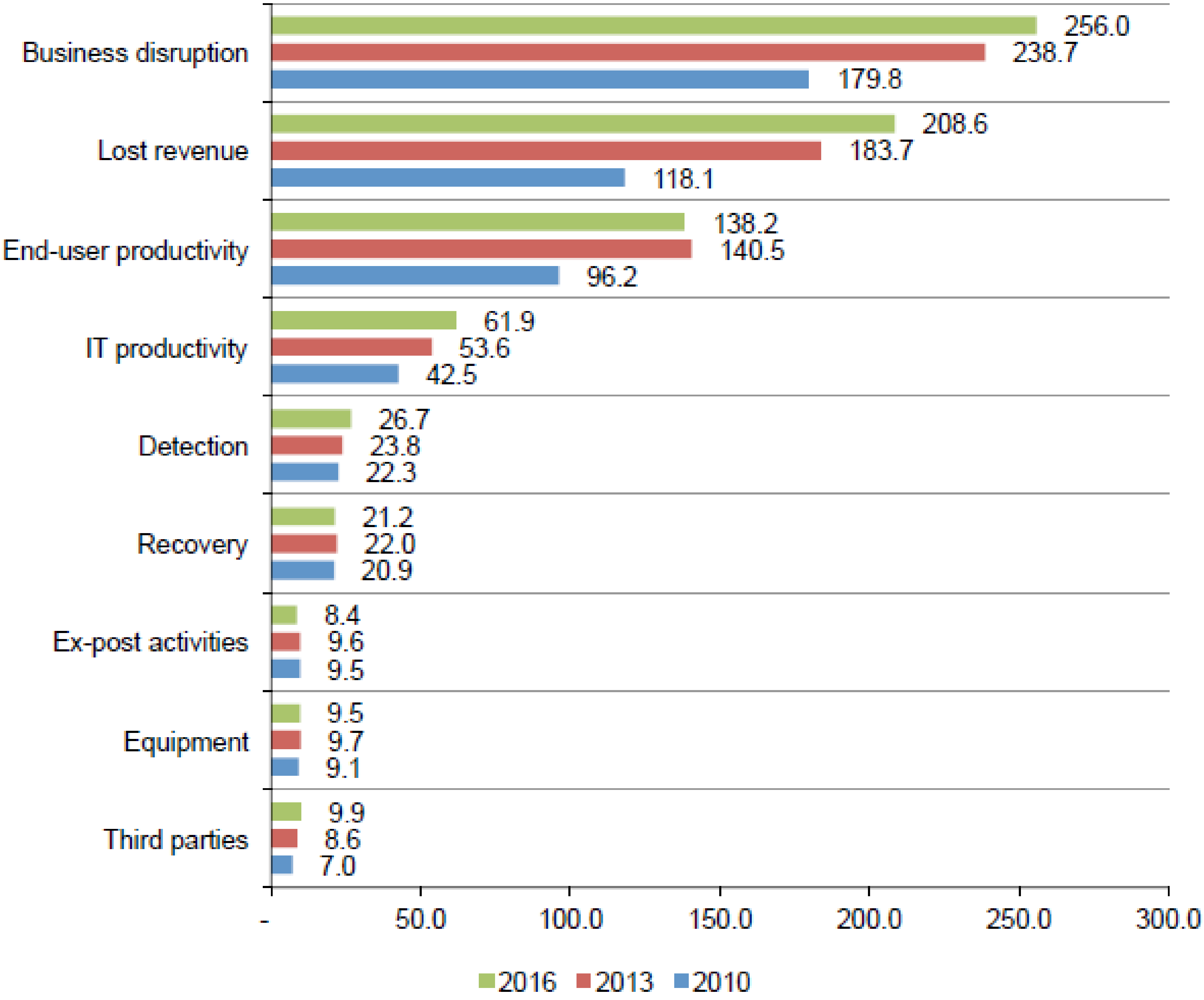
Preventative Maintenance

The Cost of Data Center Outages

- Average cost increased from $505,502 to $740,357 between 2010 & 2016
  - 38% increase
- Maximum downtime cost of the 63 data centers studied was $2,409,991
- UPS system failure still the number one cause

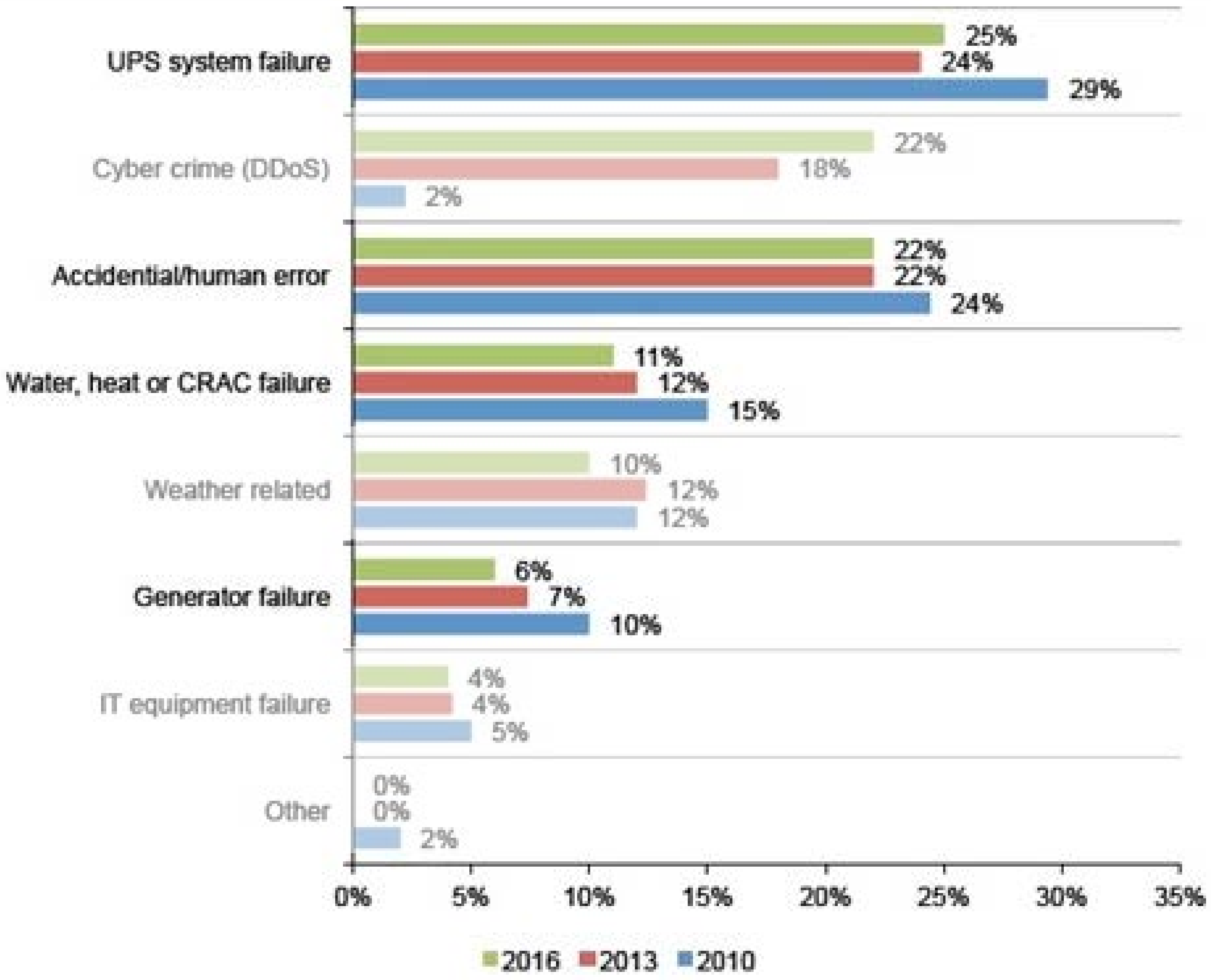
Preventative Maintenance

The Cost of Data Center Outages



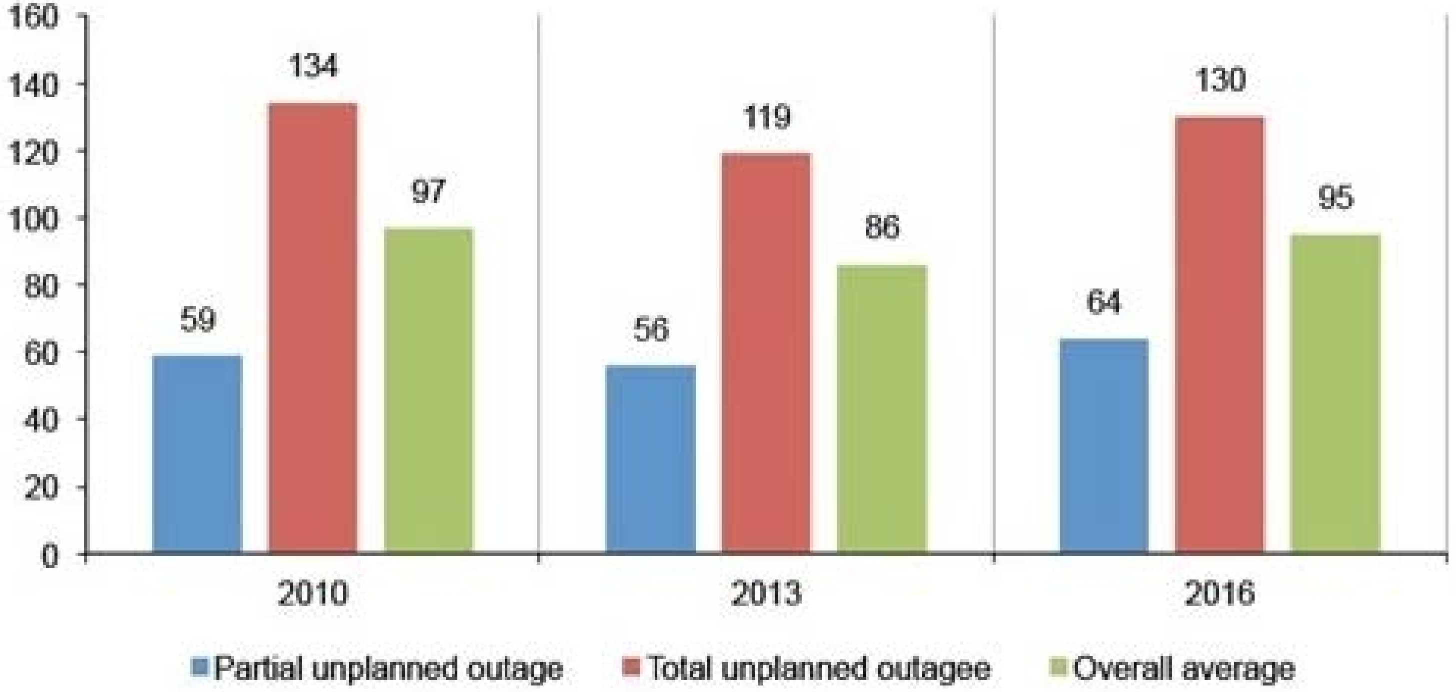
Preventative Maintenance

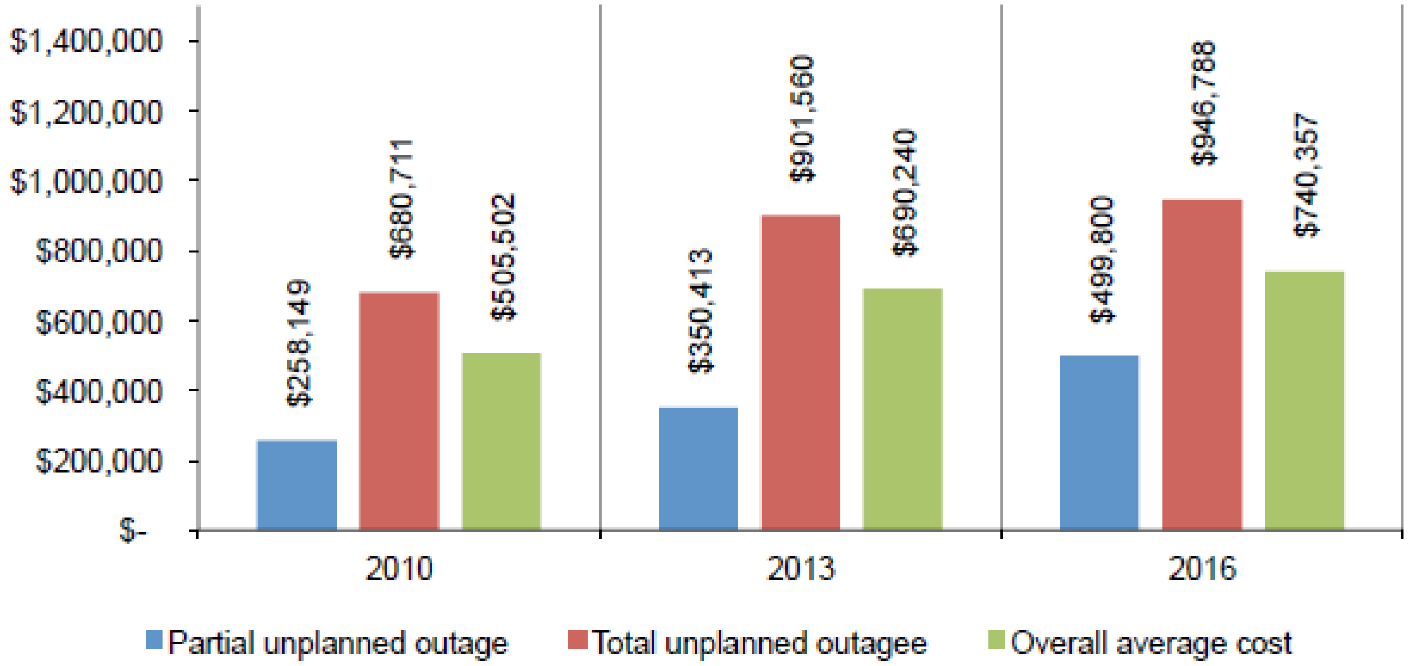
The Cost of Data Center Outages



Preventative Maintenance

The Cost of Data Center Outages





Preventative Maintenance

Choosing an Approach

- Run to failure
  - Reactive

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  - Test & trend, then react

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  - Based on run time, condition, or operator recommendation

Preventative Maintenance

Choosing an Approach

- Run to failure
  - Reactive
- Predictive or condition-based maintenance
  - Test & trend, then react
- Preventative or condition-based
  - Based on run time, condition, or operator recommendation
- Reliability Centered Maintenance (RCM)
  - When it is too big or too expensive to treat every component the same

Reliability Centered Maintenance

Defined

- Determines a logical way to determine if a PM makes sense for a given item
- Preserves system functionality
- Focused on the system rather than the component
- Acknowledges design limitations
- Is an ongoing process

Reliability Centered Maintenance

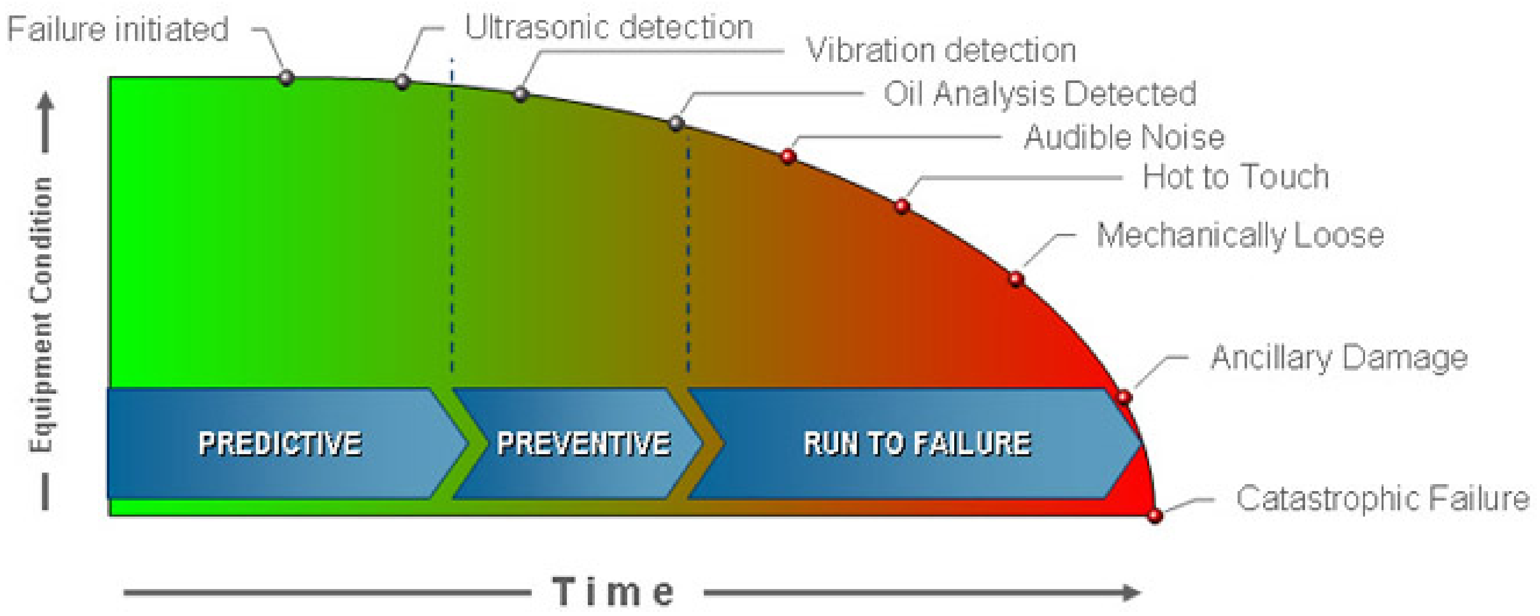
Elements

- Functions of equipment
- Functional failures likelihood
- Failure modes/failure analysis
- Failure effects/logic tree analysis
- Failure consequences
- Mean Time Between Failure Calculations
- Proactive tasks, task intervals
- Default actions

Reliability Centered Maintenance

Elements

- What does the asset do
- How can the asset or its sub-components fail
- What are the likely failure modes
  - Fail to Bypass, EPO
- What are the likely chain of events associated with the failure
- What are the Costs associated with the failure



Preventative Maintenance

From Design to Commissioning Through End-of-Life

- Design
- Acceptance testing (commissioning)
- Develop commissioning plan
- Develop scripts
- Execute test
- Training
- Preparation, records, procedures, and tools for maintenance

Project Example

Internet Service Provider Learns Value

- CTs tested
- Relays tested
- Interconnect wiring not proven via current injection
- Differential circuits wired improperly
- Caused startup delays because generators wouldn't stay connected to the bus

Project Example

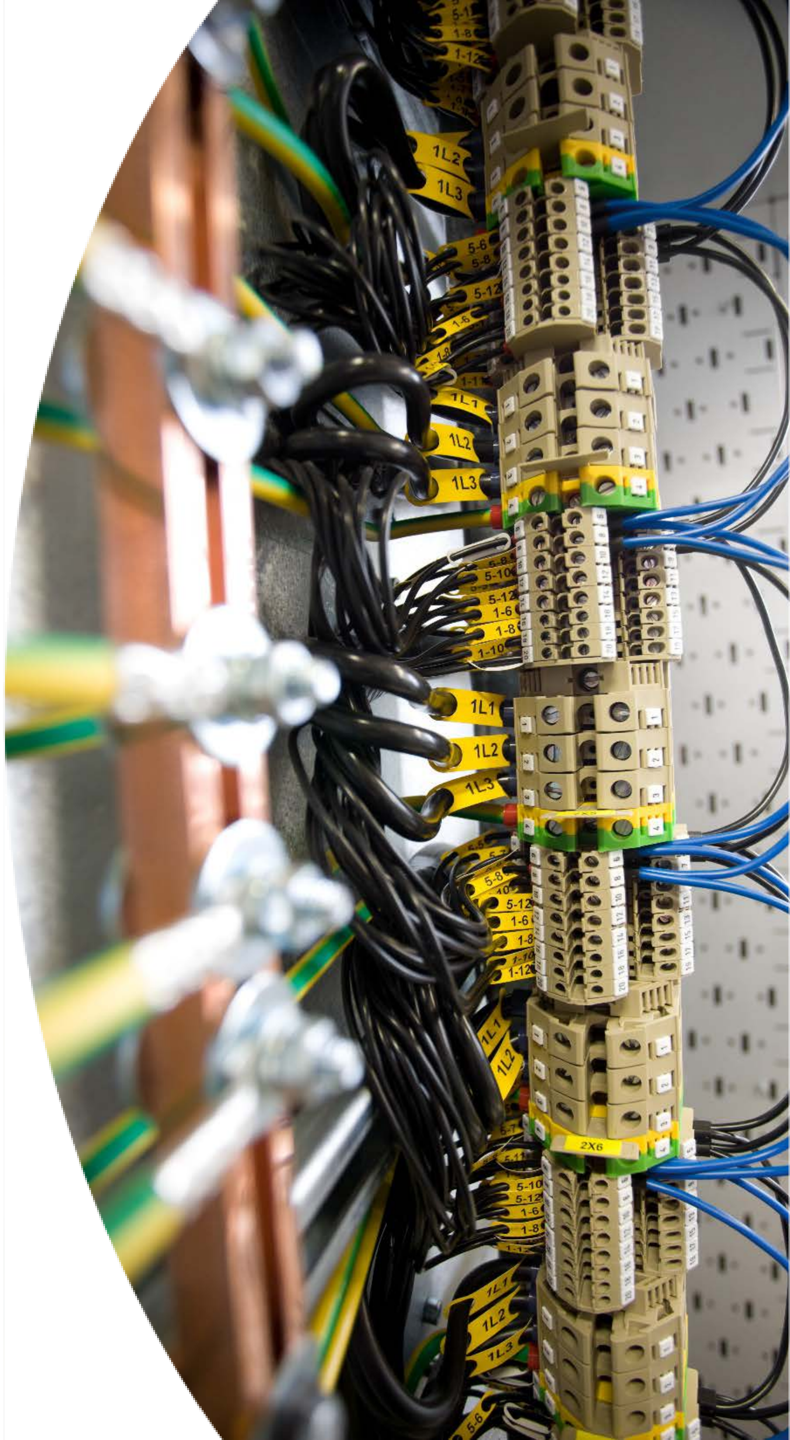
Wireless Communication Company Loses Access

- Electrical and mechanical systems were tested and commissioned
- Did not fail power to individual panels
- Facility-powered gate did not have manual release
- No walk gate
- Facility drops critical load after a generator failure while fire department cuts gate open

Project Example

BMS System Operational Shortcut

- Abbreviated Cx does not reveal system timer settings
- Back up air cooled chillers shut down after 45 minutes after transfer



Establishing a Program

Consider Your Unique Business Situation

- Business model and objectives
  - System design
  - Growth strategy
  - Work blackout periods
  - Customer requirements/Service Level Agreements
- Risk tolerance
  - IT redundancy
- Operating cost control priorities
  - Improving energy efficiency
  - Extending equipment lifecycles
  - Reducing/mitigating downtime

Establishing a Program

Facility Factors to Consider

- Future Use
- Site expansion strategy/capability
- Design deficiencies and challenges
  - Redundancy (or lack thereof)
  - Physical constraints
- Environmental considerations
  - Seasonal impact on energy consumption
  - Location/regional impacts

Establishing a Program

Facility Factors to Consider

- Safety is paramount. Always.
  - Proper labeling
  - Lock out/tag out
- Installed equipment
  - Existing maintenance agreements/warranties
  - Legacy equipment service/parts availability
  - Manufacturer recommendations
  - Criticality of components

Maintenance Program

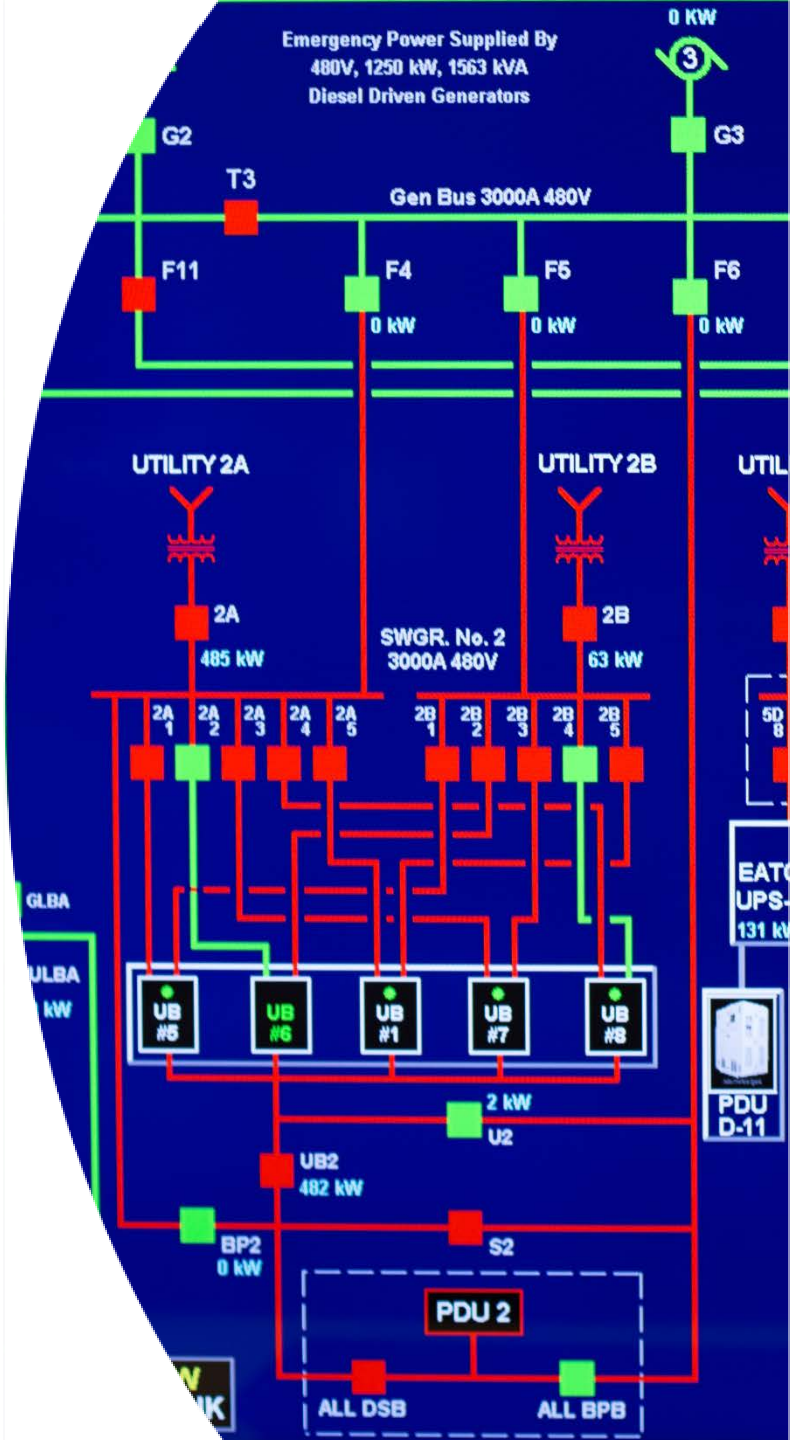
Facility Factors to Consider

- Maintain vs. replace
    - Consider total cost of ownership
    - Expected lifespan remaining
    - Physical access constraints
    - Availability of parts/qualified repair technicians
- System redundancy
    - Affects how maintenance is conducted

Equipment Maintenance

Resource Considerations

- Standard procedures
  - Operating
  - Maintenance
- Accurate drawings and documentation
- Realistic schedules
- Maintenance personnel
  - In-house or outsourced
  - Vendor selection
  - Capabilities



Maintenance Program

Logistical Considerations

- Restricted access/maintenance times
  - Additional costs such as after-hours/weekend shut down, load transfer, etc.
- Resources and training of personnel
  - In-house support staff
  - Equipment manufacturer staff
  - 3rd party consultants
  - Maintenance service provider

Equipment Maintenance

Personnel Safety

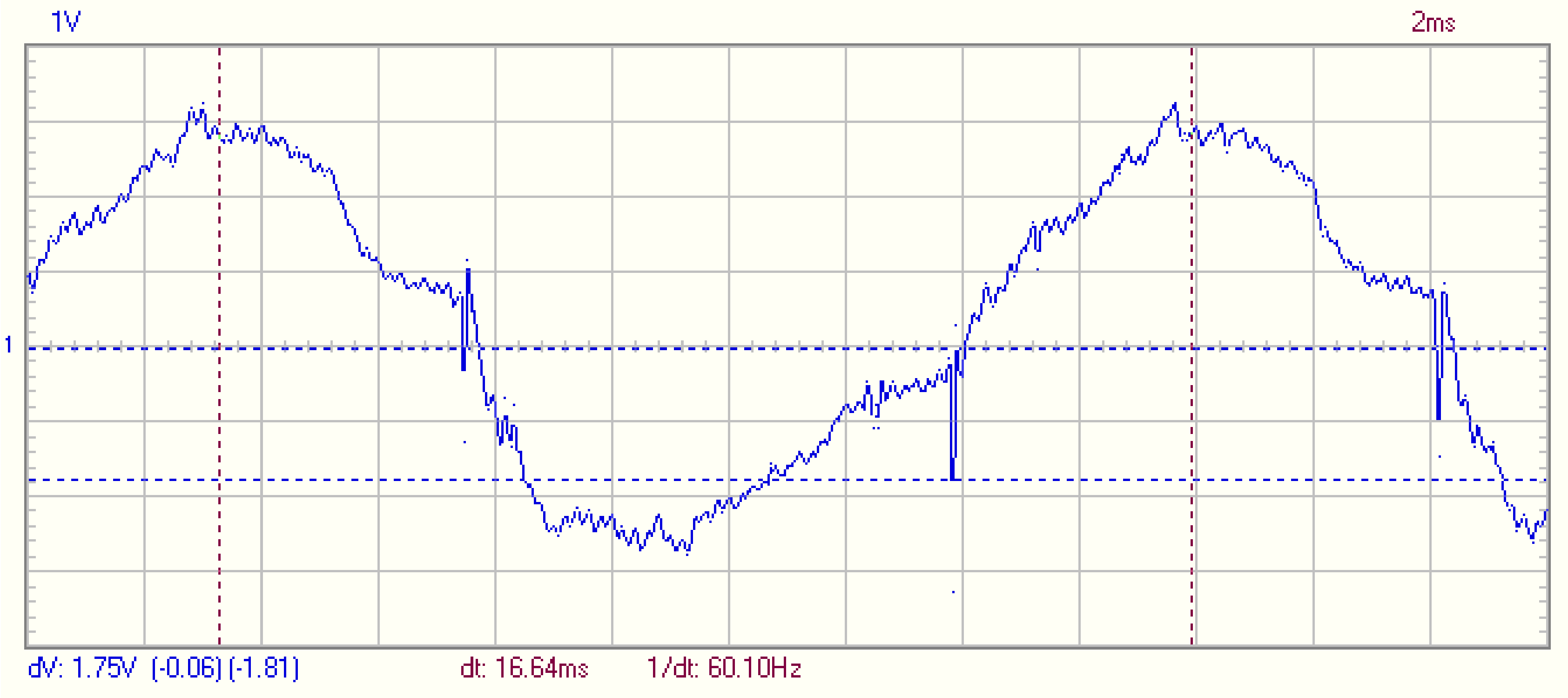
- NFPA 70E
- Proper grounding during maintenance

System Studies

- Power Quality
- Short Circuit Coordination Studies / Arc Flash Studies
- Load Flow Studies
- Reliability Studies / Risk Assessment Studies / Mean Time Between Failure Studies
- Maintenance Related Design Studies

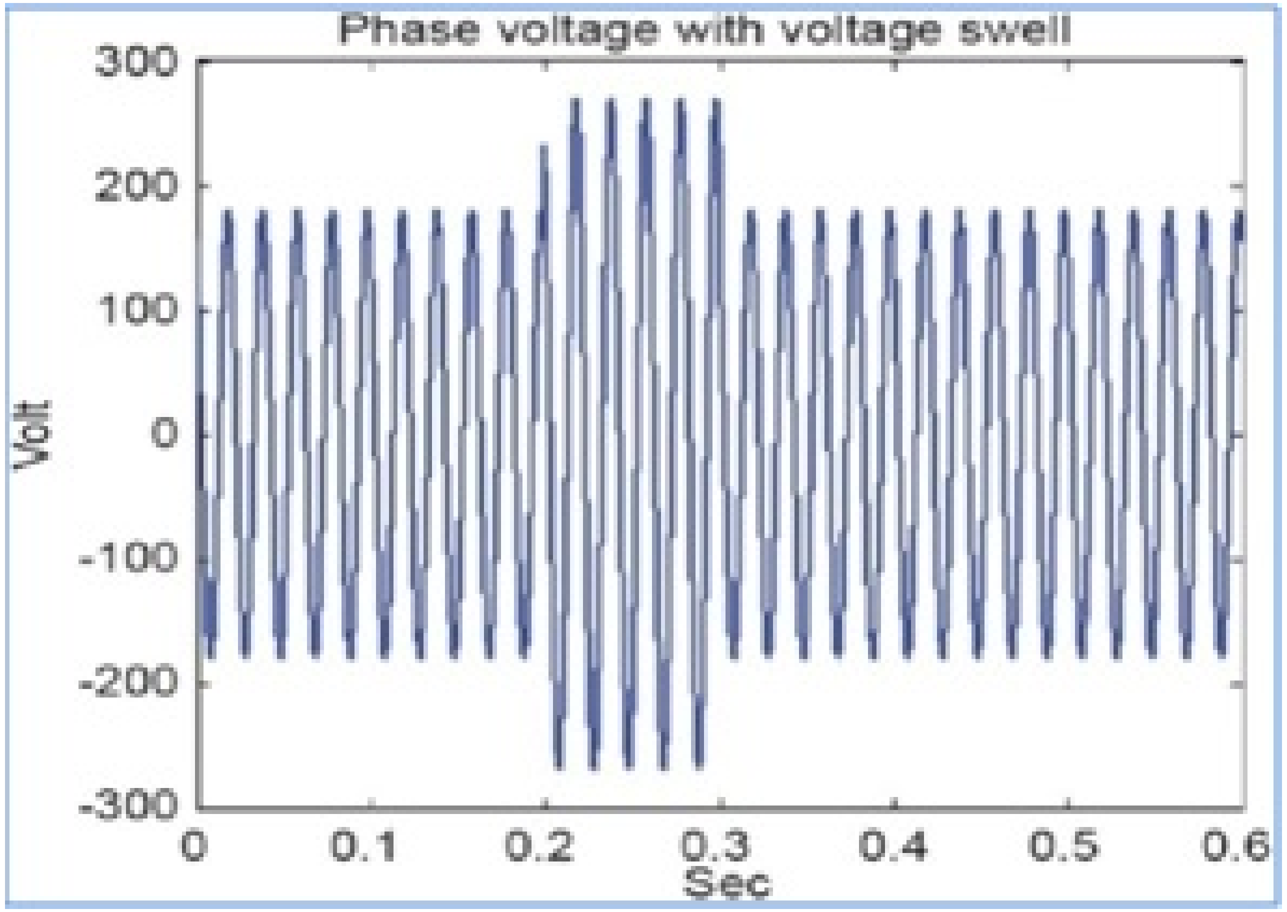
Power Quality

- Harmonics
  - Influenced voltage waveform
  - Zero crossings
  - Noise Interference
  - Equipment Failure
  - Nuisance operation
- Transients
  - Equipment damage
  - Mis-operation



Power Quality

- Voltage Sags and Swells
  - Outages
  - Equipment damage
- Unbalanced Voltages
  - Motor damage
  - Conductor heating



Testing and Test Methods

- Acceptance testing
  - Establishing your baseline
- Maintenance testing
  - Routine
  - Special
- Pretest circuit analysis
- As-found and as-left test
- Frequency of test

Electrical Equipment Maintenance

Long Intervals Between Shutdowns

- In many cases required more frequent maintenance
- More frequent non-invasive testing such as Infrared or Ultrasonic scanning
- More thorough testing when an outage can be facilitated

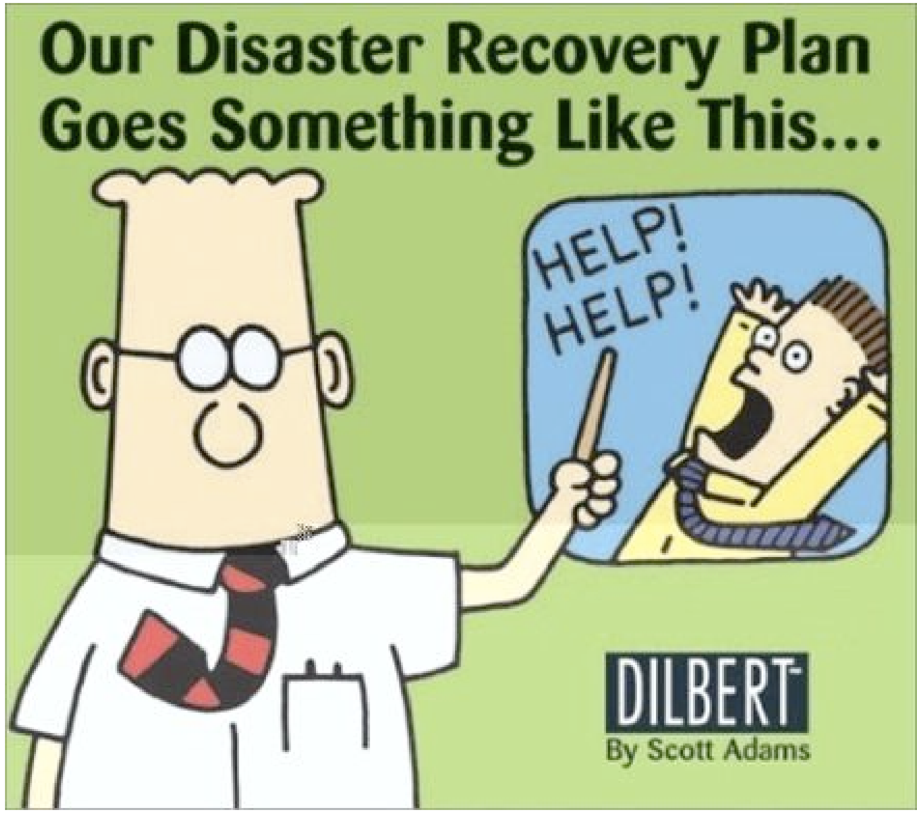
Project Example

Retail Company Cuts Power Rather than Prices

- For MV breaker maintenance, critical load transferred to system bypass
- Bypass breaker (480 volt, 4000 ampere) with new trip unit was improperly installed
  - Caused breaker to revert to 1600 ampere trip setting
    - Load was 2850 amperes
- Breaker was only secondary injection tested
  - Issue would've been found with primary injection

Disaster Recovery

- Limit damage
- Assess damage
- Prioritize the corrective action
- Repair or replace
- Execute
- Emergency Procedures
- Adequate Emergency Documentation



Changing Equipment

PV, Electrical Charging, Fuel Cells, and Wind Power Systems

- Cleaning
- Periodic maintenance
- Structural considerations
- Yaw systems
- Cable support systems
- Must develop a plan for new systems

Safety First

Arc Flash

- What is an arcing fault
- What are the danger levels
- Misunderstandings exist

Safety First

Arc Flash Considerations

- Critical power systems are complex
- Multiple energy sources
- Multiple operating modes
- Code only requires worst case conditions to be posted

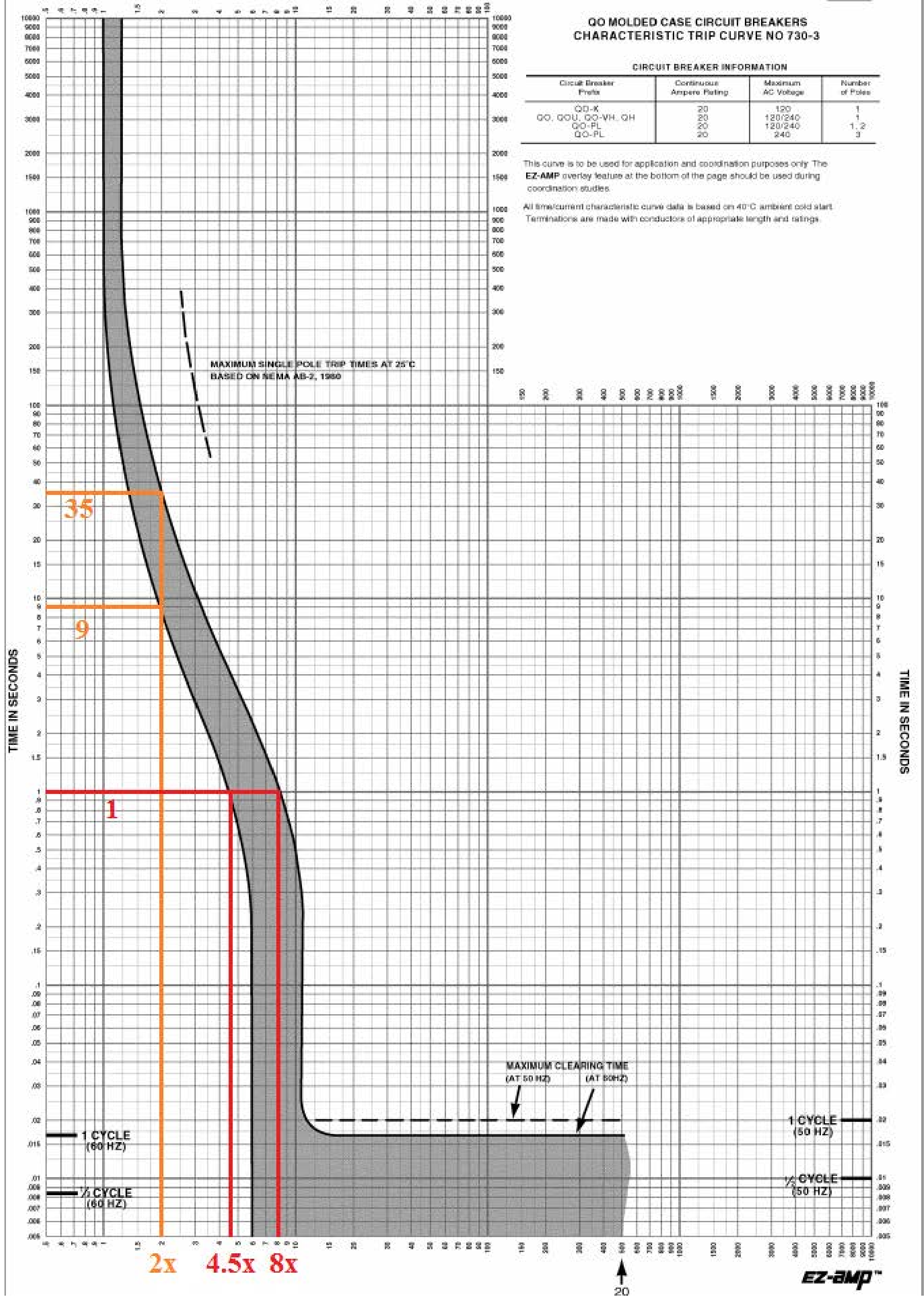
Fault Current and Incident Energy

Operating Mode	Available Fault Current	Incident Energy at UPS module A1 (cal/cm2)
Closed transition Transfer to Generators	47,490	28
Operating on Utility A	47,120	27
Operating on Utility B	40,330	122
Operating on (2) 2500 kW Generators (N+1)	23,280	82
Operating on (2) 2500 kW Generators with incident energy reduction enabled at generator main tie breaker	23,280	69
Operating on (2) 2500 kW Generators with incident energy reduction enabled at feeder breaker	23,280	2.7

Note: *Level of fault current does not correlate with the incident energy level because of the speed at which and arcing fault will be cleared*

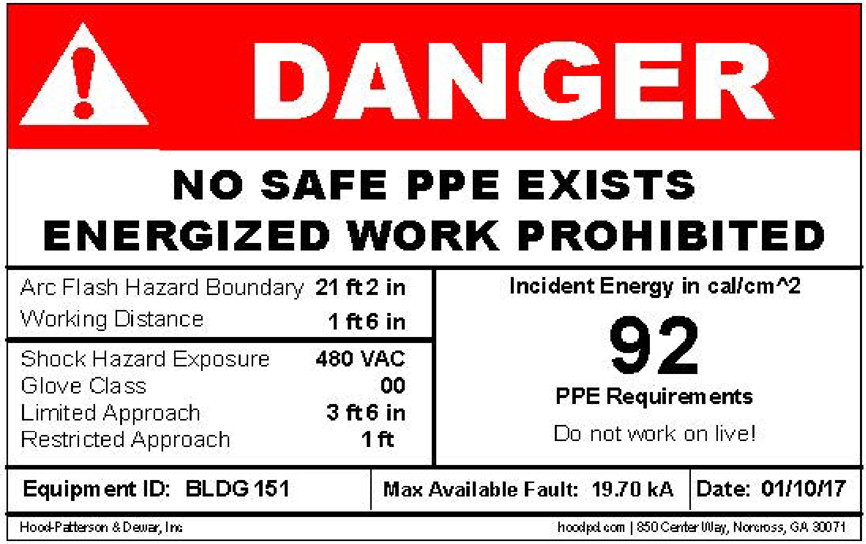
Fault Current and Incident Energy

- Depends on
  - Breaker curves
  - Breaker settings
  - Automatic failovers
- Maintenance mode switches make the most difference
- Has to be modeled to be determined



Energized Maintenance

- Arc flash mitigation
- Zone Interlock
- Incident energy reduction switches
- Label can provide energy level for additional modes



Plan Maintenance on the best Power Source

- Coordinate maintenance operations and incident energy label with operating procedures
- Limit risk by considering all the options
- Maximize maintenance access

Project Example

Major Airline, Minor Maintenance

- Significant costs due to failure
  - Flights grounded world wide for 24 hours
  - Flights cancelled, delayed or otherwise affected for 3+ days
  - Bad press, reputation

Maintenance Program

Tracking Results

- Develop metrics
- Develop Key Performance Indicators (KPI)
- Track and trend to improve the process
- Learn from each test, failure, inspection, etc.
- Modify the plan based on new information

Typical Pitfalls

- Maintenance budget is the first to go
- Afraid to operate the system
- Afraid to shut down components
- Need approval for a black hole test (pull the plug)
- Don’t learn from mistakes, they learn to run from mistakes

In Summary

- Understand your business model, strategies, challenges, and priorities
- Obtain an independent comprehensive facility assessment
- Identify existing and needed resources, procedures, and training
- Determine your preferred maintenance approach (RCM)
- Develop a plan based on your real-world facility, conditions, and requirements
- Track and trend KPI to monitor results and promote continuous improvement
- Don’t generalize

Thank You

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