# Facility Maintenance Best Practices

## Making the Most of What You Have

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hood patterson & dewar

# 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

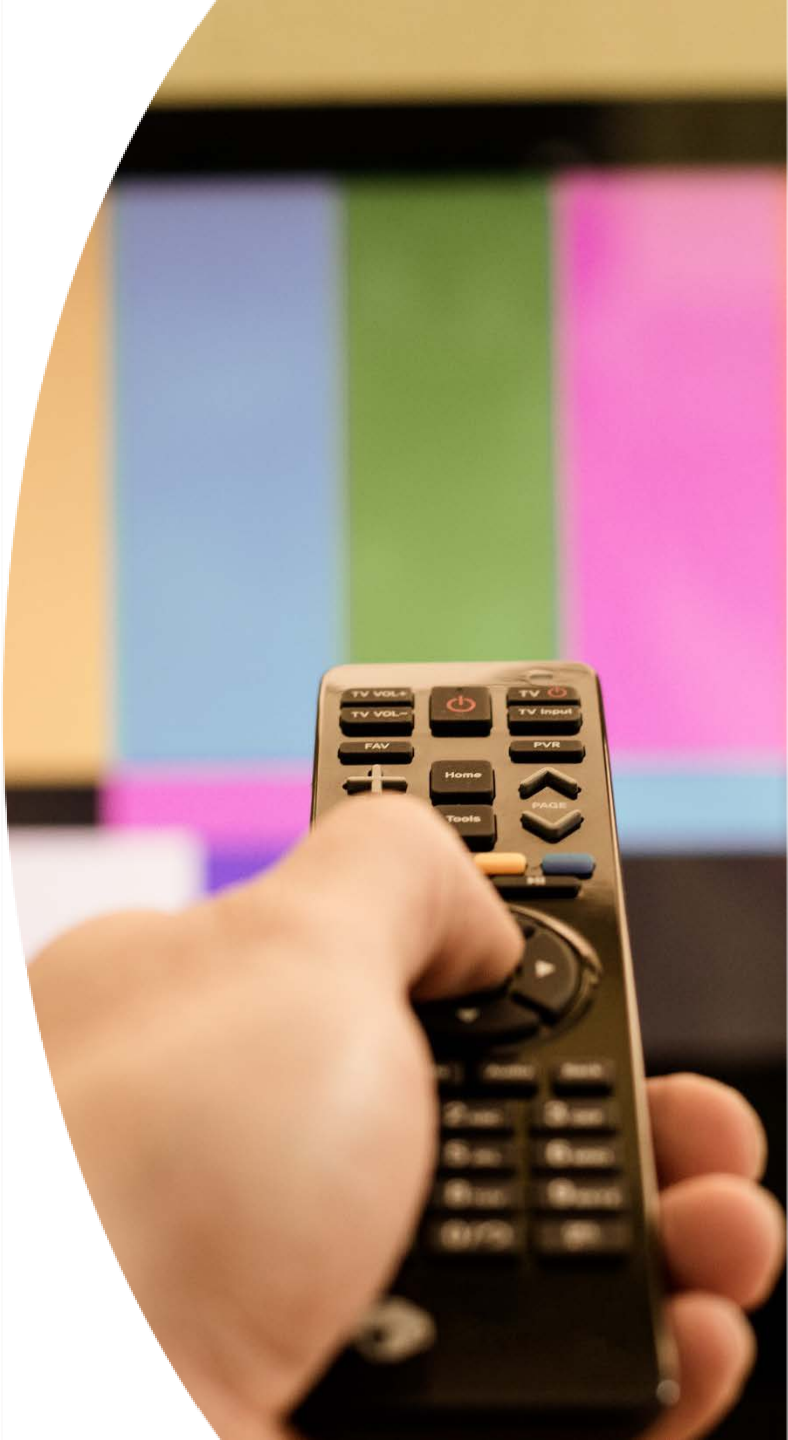
Credit Card Company has Facilities and IT disconnect

- 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- Equipment is out of date and needs upgrade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

# 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

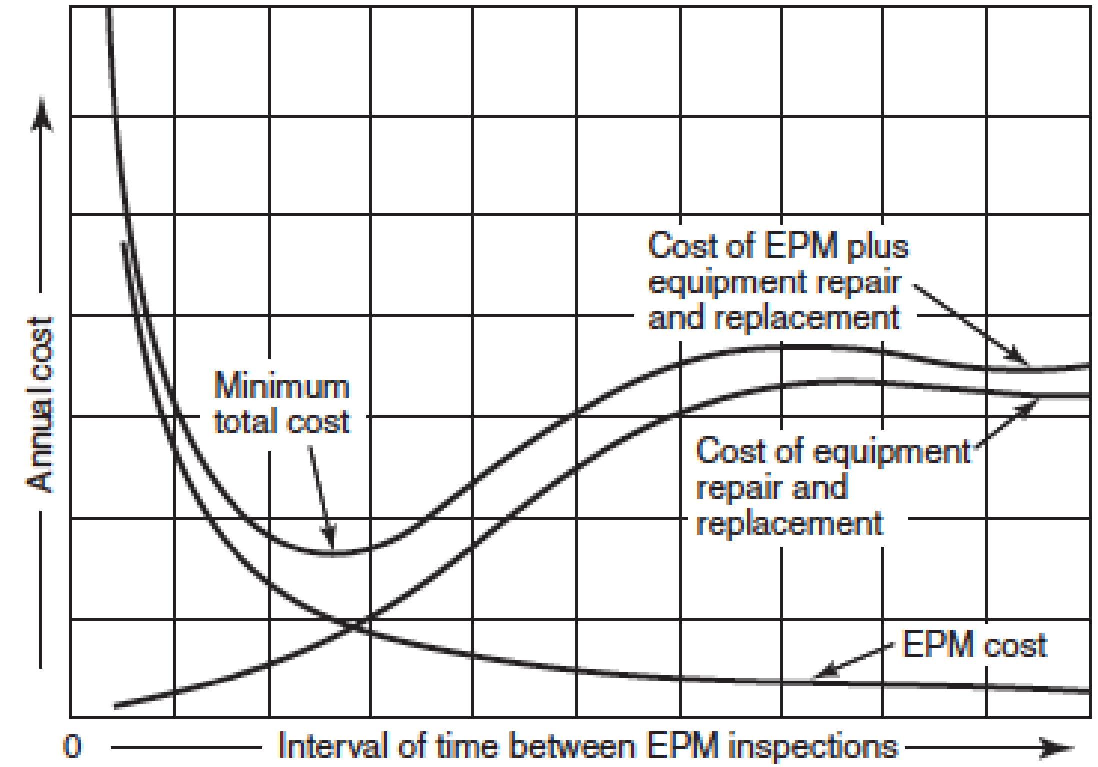
## Reference Publications

- 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

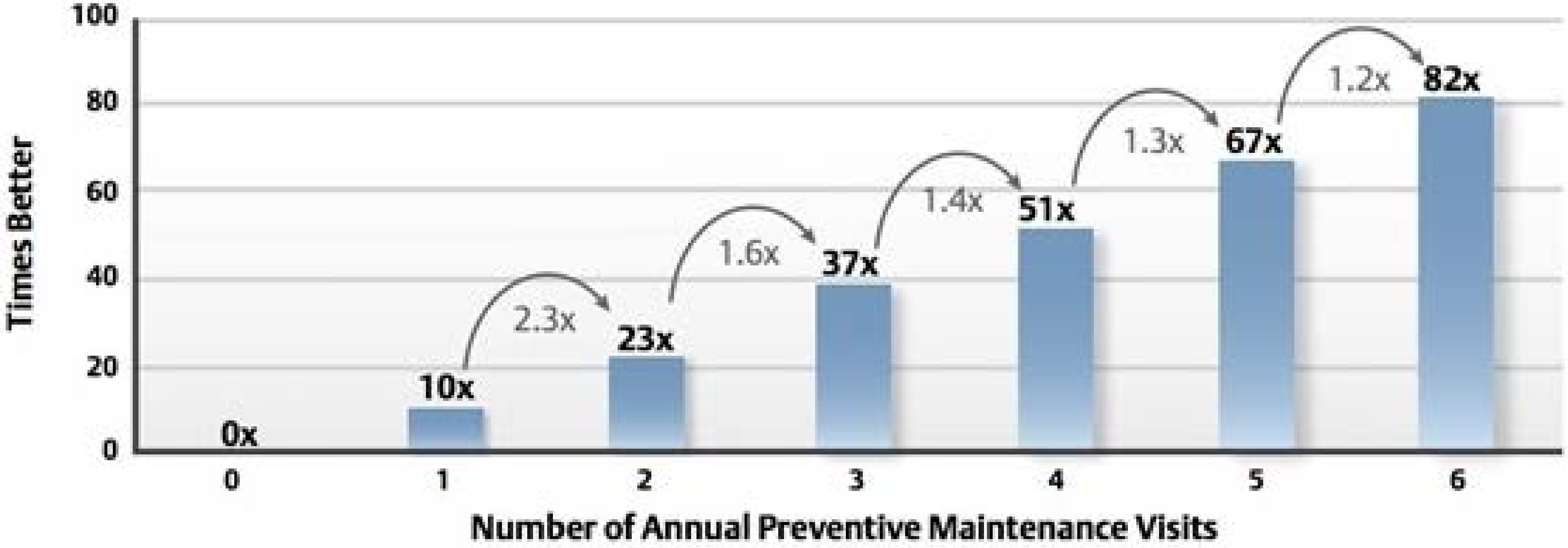
# Preventative Maintenance

How often?

- Inspection Frequency
- Maintenance Frequency
- Replacement Frequency



# Preventative Maintenance Frequency Impact



# 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

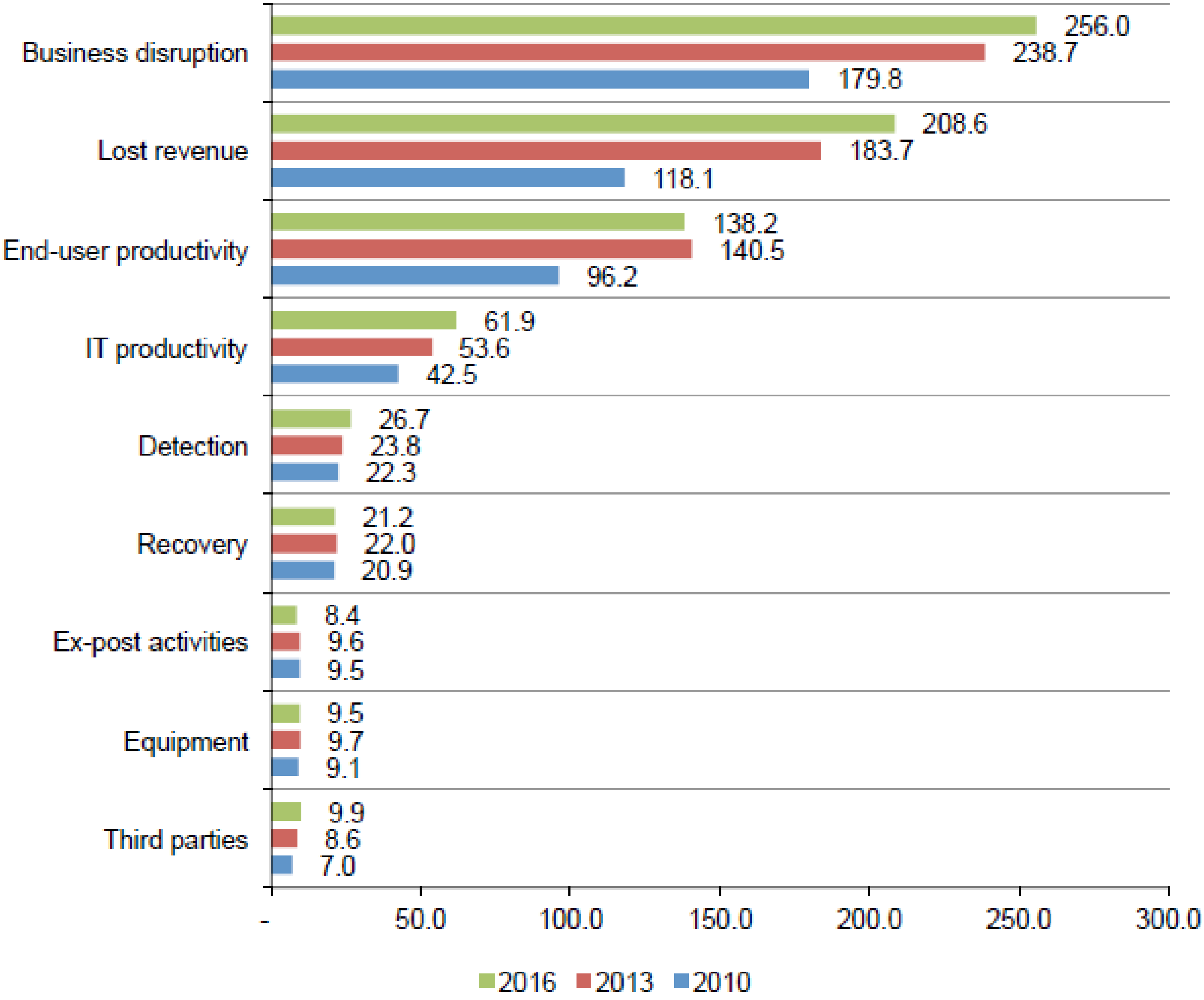
# Preventative Maintenance

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

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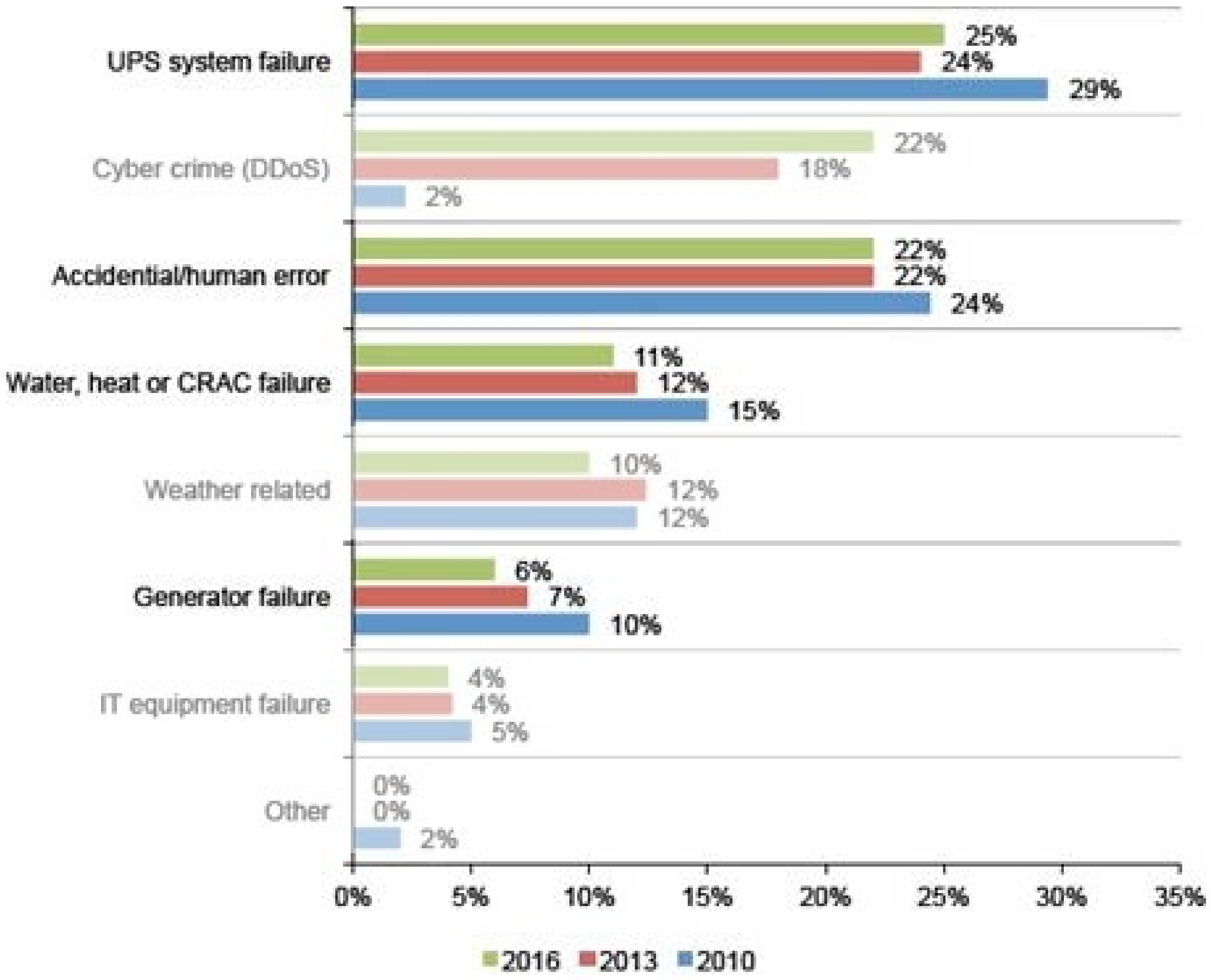
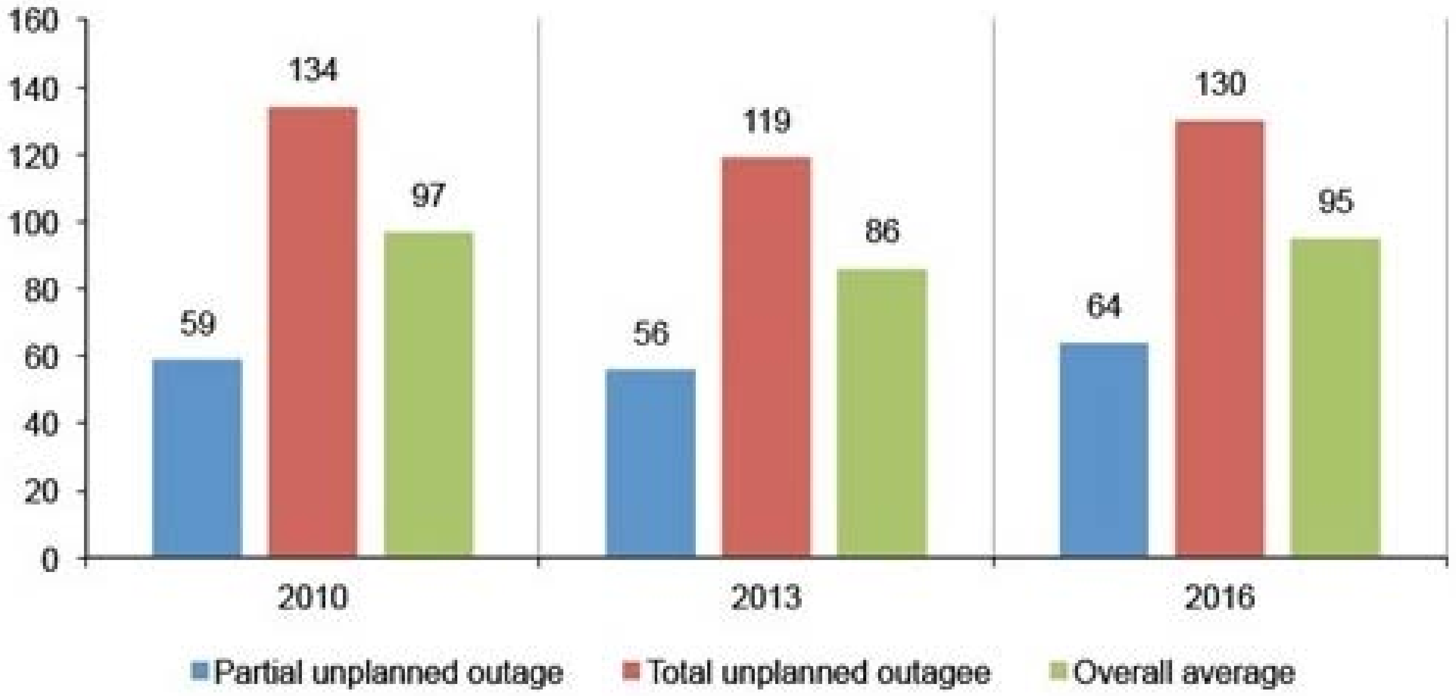
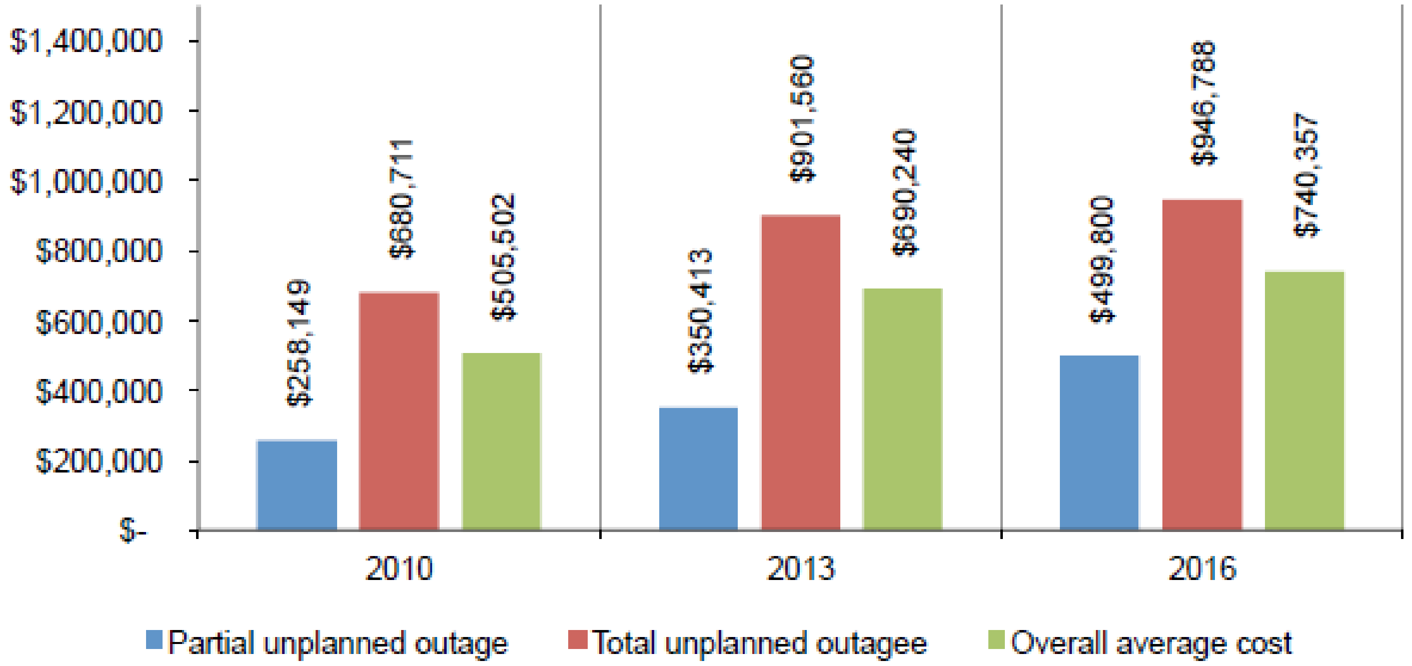


# Preventative Maintenance

The Cost of Data Center Outages



# Preventative Maintenance

## Choosing an Approach

- Run to failure
  - Reactive

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# Preventative Maintenance

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- Run to failure
  - Reactive
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  - 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

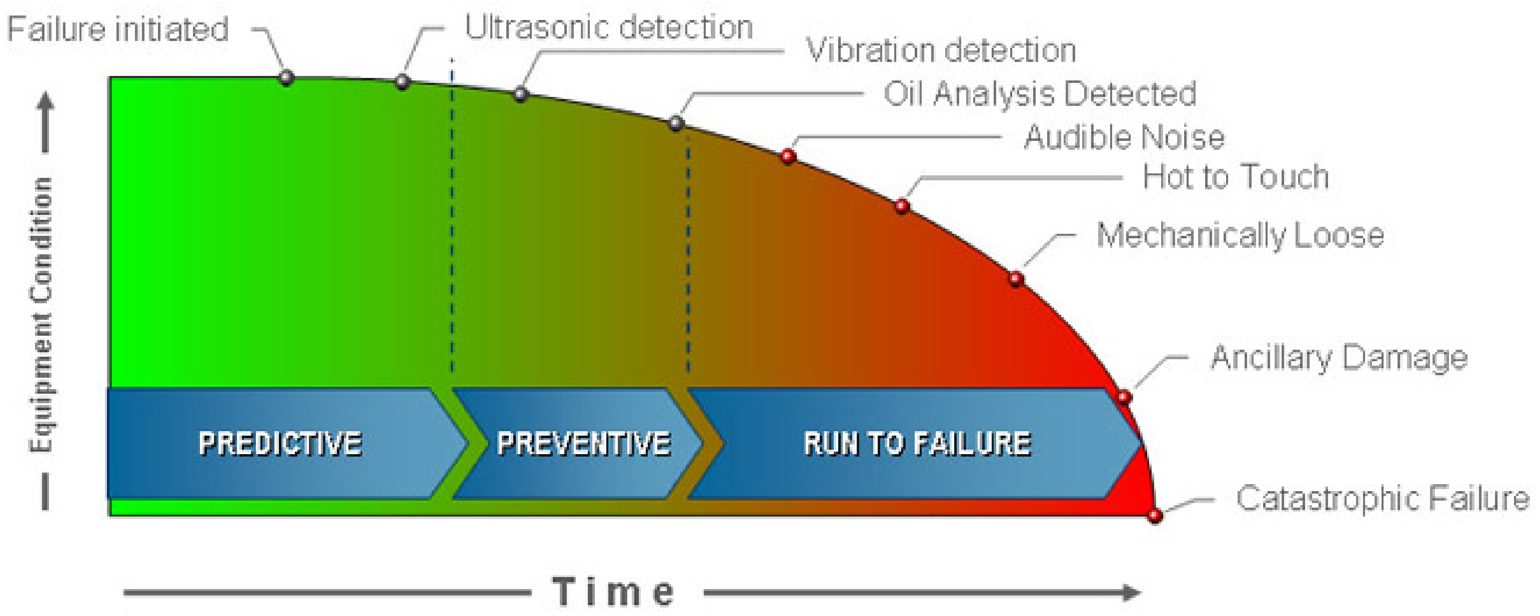
## Elements

- 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

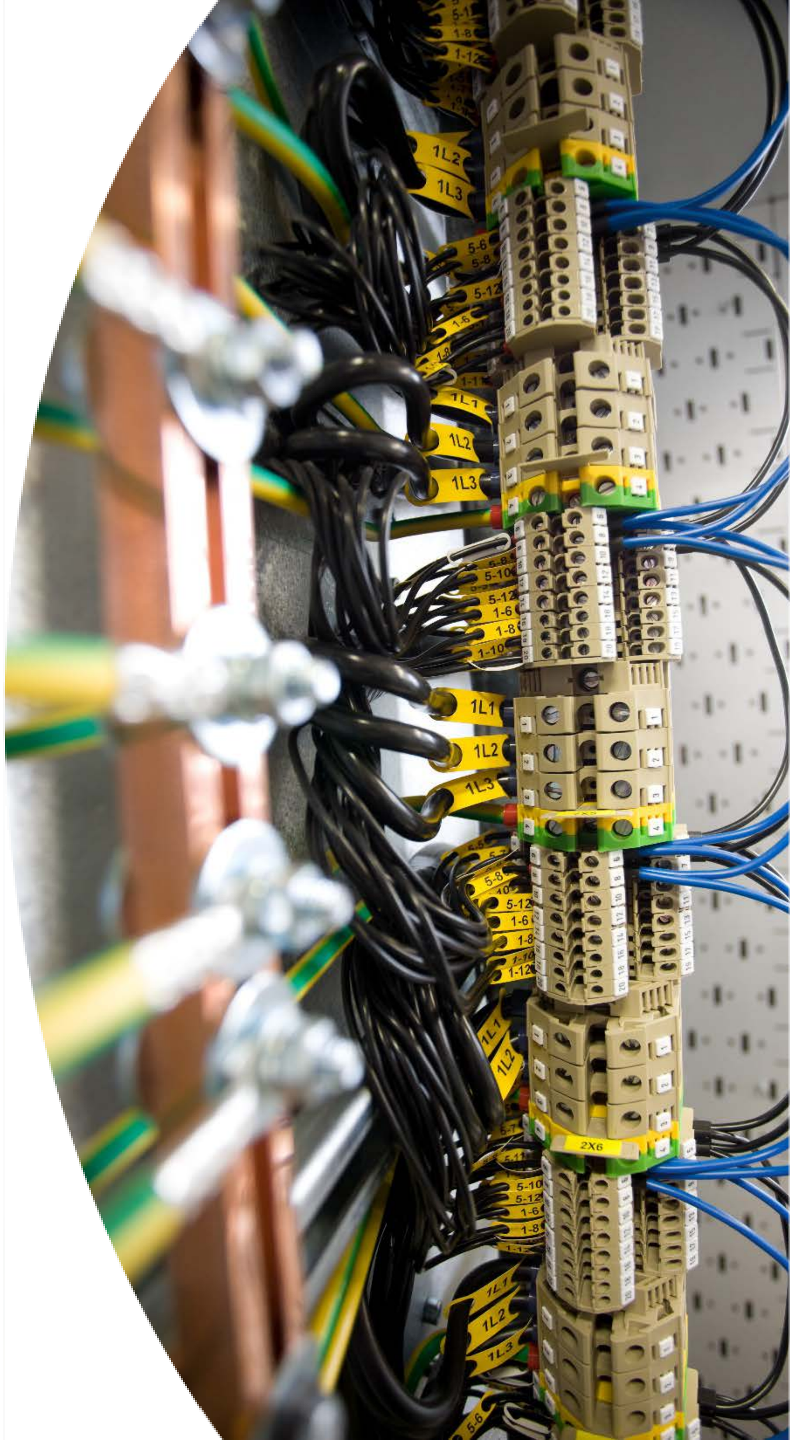
Wireless Communication Company Loses Access

- 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

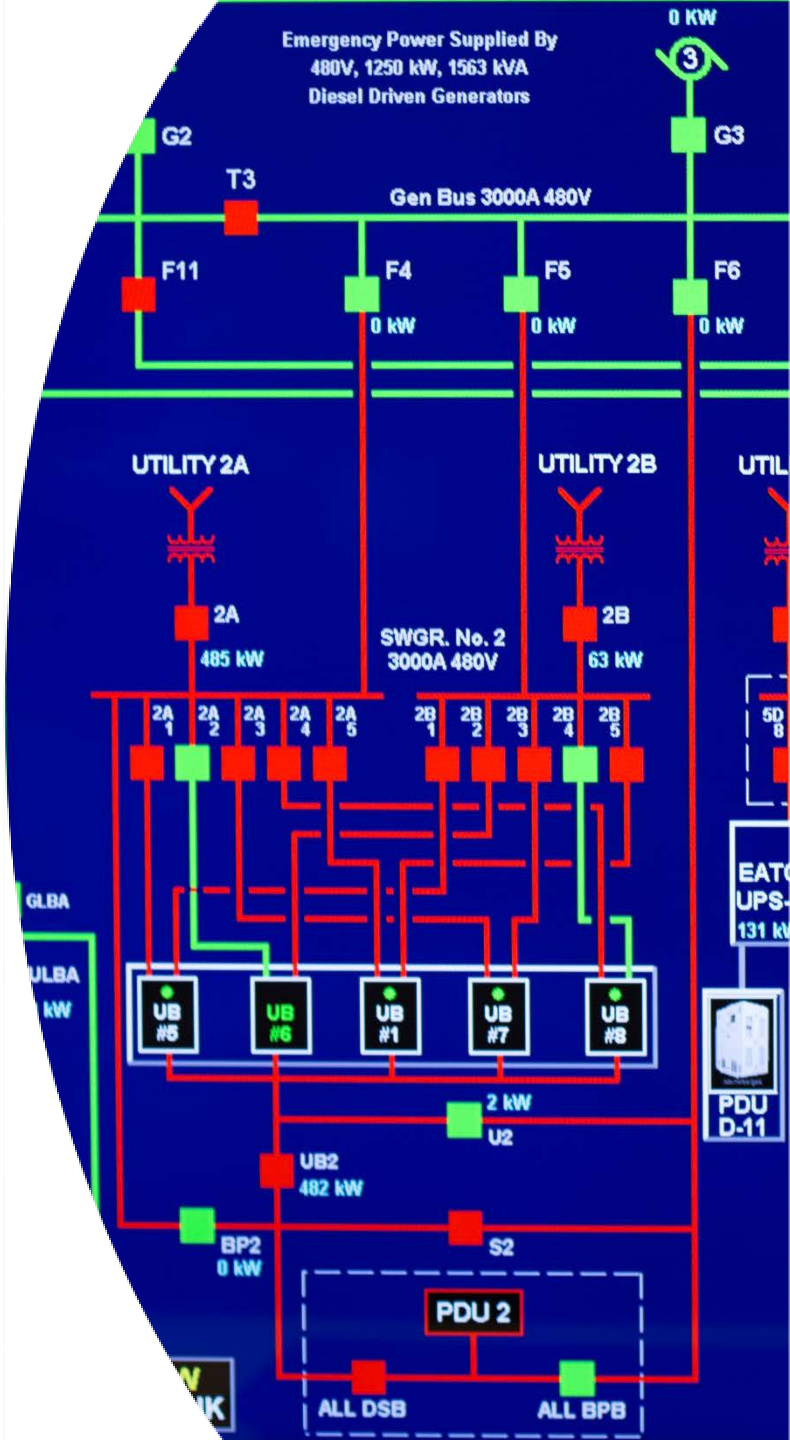
Facility Factors to Consider

- 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

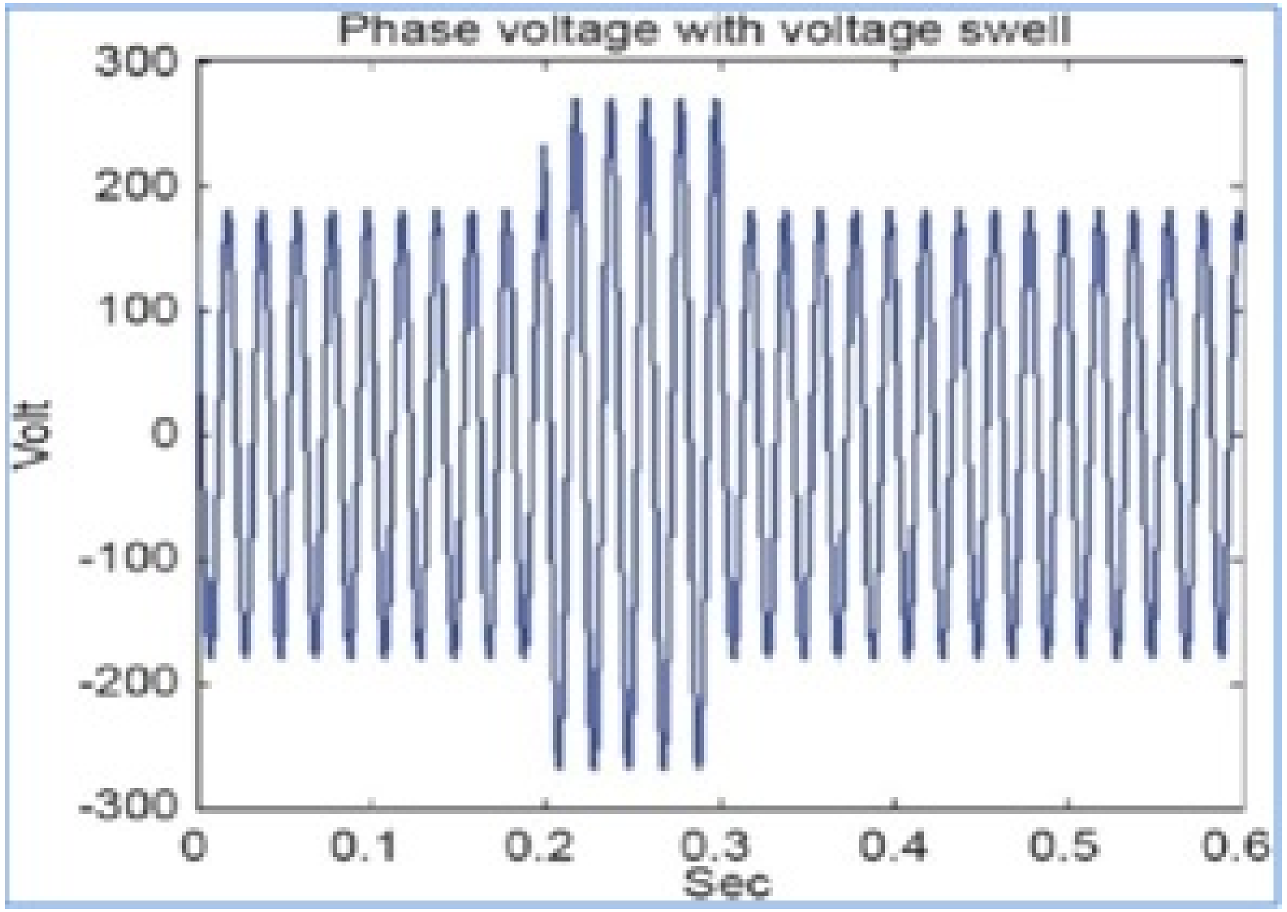
- Power Quality
- Short Circuit Coordination Studies / Arc Flash Studies
- Load Flow Studies
- Reliability Studies / Risk Assessment Studies / Mean Time Between Failure Studies
- Maintenance Related Design Studies

# 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

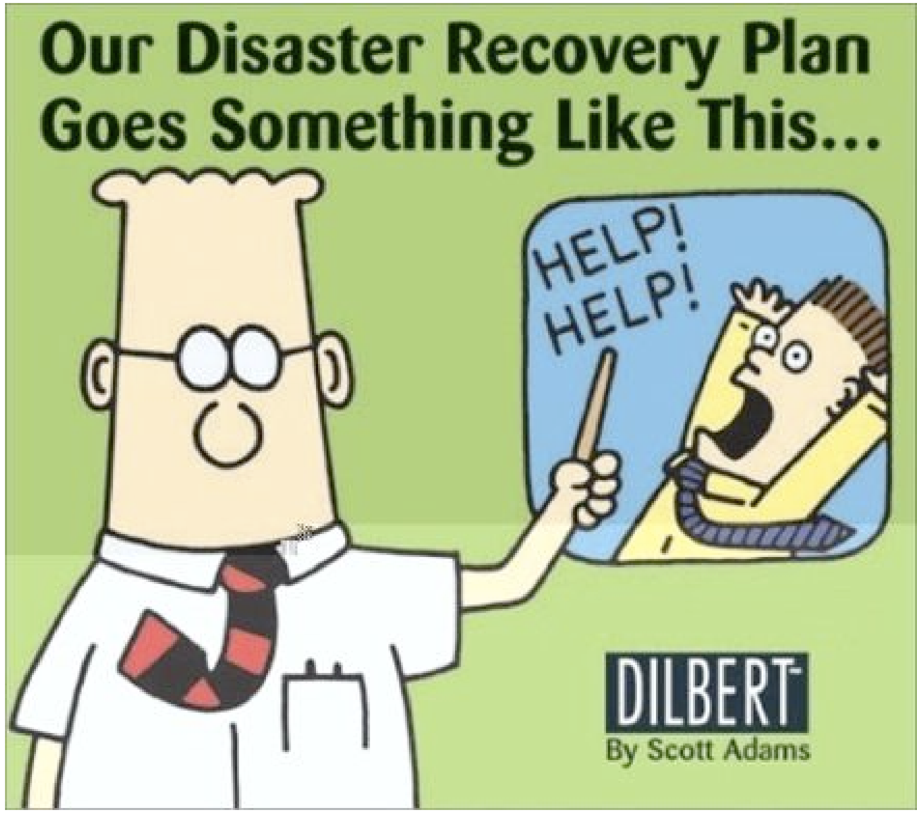
# Project Example

## 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

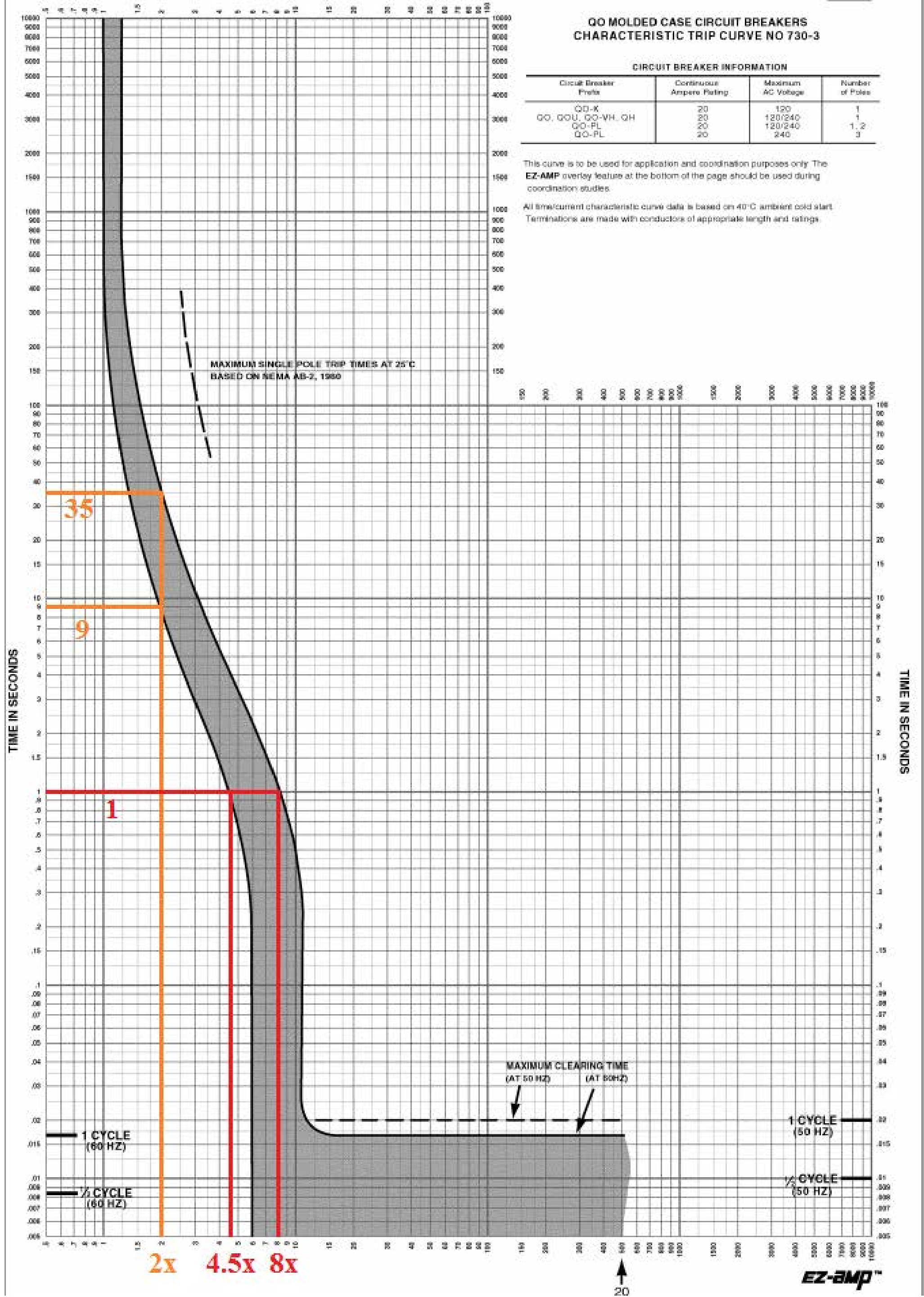
# Fault Current and Incident Energy

| 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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