

Alternating Current (AC) Substations

Sustain Program

Asset Management Strategy

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March, 2012

Agenda

➔ Executive Summary

What equipment is covered?

Strategic environment & drivers

Strategies

Process improvements

Equipment Strategies

- Power transformers and reactors
- Switchgear
- Shunt capacitors
- Instrument transformers and surge arresters
- Station auxiliary
- Substation bus & structures

What will it cost?

Program Accomplishments FY10 & FY11

Executive Summary

BPA's Alternating Current (AC) Substation Assets

- There are approximately 250 alternating current (AC) Substations on the BPA system
 - Over 50 of the 250 substations operate at 500 kV
- AC Subs represent 39% of BPA's transmission asset base

- Per a benchmarking study conducted by 1st Quartile in May 2011
 - BPA's substations are older than most other surveyed utility's substations
 - Overall capital spending at BPA (activity-based) is lower than average, and our replacement rate is low in comparison to those other utilities

Executive Summary, cont.

AC Substation Equipment Types

BPA operates approximately 27,000 major (serial numbered) pieces of high voltage electrical outdoor substation equipment and another 5,000 with limited attribute data. The AC Substations sustain program assets include the following:

- Transformers and Reactors
- Circuit Breakers and Switchgear
- Shunt Capacitors
- Instrument Transformers and Arresters
- Station Auxiliary
- Substation Bus and Structures

Executive Summary, cont.

Strategic Drivers

- Manufacturing practices and vendor support are changing, however, and the new practices are forcing electric utility and transmission providers to replace equipment earlier than in the past.
 - Newer equipment has shorter life span
 - Long term vendor support is becoming increasingly limited
 - Affects spare parts availability and cost
 - System capacity is increasing while equipment operating margins are decreasing due to age and/or effective life cycle
 - Technology obsolescence
 - Workforce obsolescence
- Transmission will continue to promote standardization in the purchase of new equipment that meets system operating requirements which will balance warehousing costs of spare parts while continuing to support maintenance activities. This effort also helps mitigate spare parts unavailability and lack of vendor support of obsolete equipment.

Executive Summary, cont.

Criteria For Asset Replacement

Assets are targeted for replacement based on the following key drivers:

- Asset Condition Assessment
- System Upgrade (Capability/Capacity)
- Asset Risk (Failure and Consequence)

Executive Summary, cont.

Replacement Strategy

- Historically, BPA has replaced AC substation equipment based primarily on failures and failure rates.
- Approximately 85% of breakers are replaced today due to the inability to obtain spare parts, unacceptable lead times for obsolete spare parts and/or excessive cost of re-manufacturing obsolete spare parts.
- A more strategic approach where assets are proactively maintained and replaced for optimized risk management based on the strategic drivers is being developed.

Executive Summary, cont.

Replacement Strategy

- The strategy is focused on four key areas for all major equipment groups:
 - Performance monitoring and data analysis
 - Maintenance and Operations approaches
 - Equipment standardization
 - Maintaining a proper level of equipment spares

Executive Summary, cont.

Transformers and Reactors

Over a 10 year planning horizon

- Replace 6 – 500kV, 7 – 230kV and 4 – 115kV transformers
- Replace 3 – 500kV shunt reactors
 - Based on statistical calculations and mean time between failures.
- Maintain the proper level of spare transformers and reactors based on BPA's sparing strategies in the event of a transformer/reactor failure.

Executive Summary, cont.

Circuit Breakers and Switchgear

Over a 10 year planning horizon

- Replace 37 - 500kV air blast and gas blast circuit breakers, as well as 67 – 230kV, 78 – 115kV and 41 – 69kV and below circuit breakers
 - Based on age, obsolescence and effective life-cycle
- Replace 7 – 500kV Mark IV circuit switchers on reactor positions, as well as 31 – 230kV, 22 - 115kV circuit switchers of various technologies
 - Due to end of mechanical life and technological obsolescence
- Replace 163 – 230kV, and 106 – 115kV disconnect switches
 - Based on age, lack of spare parts, effective life cycle and identified safety issues.

- Emergency spares are maintained at a proper level to have at least one spare that can be applied to each voltage class in the event of failure.

Executive Summary, cont.

Shunt Capacitors

Over a 10 year planning horizon

- Replace 1 – 115kV shunt capacitor group
 - Based on age, condition and effective life cycle.
- Replace all capacitors in 1 – 115kV and 1 – 500kV shunt capacitor group
 - Due to manufacturer defect.
- Add current limiting reactors at 3 sites
 - To eliminate existing operating restrictions.
- Spare capacitor cans and fuses are stocked to an appropriate level.

Executive Summary, cont.

Instrument Transformers and Arresters

Over a 10 year planning horizon

- Replace the remaining 1,100 instrument transformers containing PCBs \geq 50PPM
 - Regulated by the Toxic Substance Control Act
- Replace 440 SiC arresters
 - Based on age, condition and effective life cycle
- Replace rod gaps with arresters on 17 – 500kV line terminals, and 48 – 230kV and 115kV line terminals and transformers
 - Reduce momentary outages thus increasing reliability
 - Improved insulation coordination
- Emergency spares are maintained at a proper level to have at least one spare that can be applied to each voltage class and rating in the event of failure.

Executive Summary, cont.

Low Voltage Auxiliary

Over a 10 year planning horizon

- Replace 112 DC control batteries and chargers
 - Based on age, condition and effective life cycle.
- Upgrade station service at 44 substations
 - Based on the age, condition and effective life cycle of the equipment and cabling
- Emergency spares are maintained for station service equipment at a proper level to have at least one spare that can be applied to each voltage class in the event of failure.

Executive Summary, cont.

Substation Bus and Structures

Over a 10 year planning horizon

- Replace the bus at 4 substations
 - Based on age, condition and effective life cycle
- Replace multiple foundations at 13 substations
 - Based on age, condition and effective life cycle
- Replace 35 engine generators
 - Based on age, condition and effective life cycle
- Perform seismic upgrades on 42 – 500kV line terminals

Executive Summary, cont.

Capital Forecast Based on Asset Strategy

Capital Plan for Subs AC, FY12 to FY21 (\$1,000s)

	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19	FY20	FY21	Total
Current Strategy	\$21,931	\$25,855	\$26,940	\$29,673	\$35,293	\$31,120	\$31,378	\$33,208	\$29,310	\$28,409	\$293,118

Impacts of Constraints on Budget, Resources, Outages, etc.

Potential impacts from not fully funding the proposed asset strategy due to budget constraints include the following

- Asset Performance Objectives and Targets
 - Corrective maintenance costs will rise or remain high on equipment in poor health or reaching it's effective life-cycle
- Asset Failure
 - Vendor support for some equipment is becoming scarce or non reliable
 - May be more emergency replacements of circuit breakers and circuit switchers
 - Will risk a run to failure approach on some assets thus replacing under emergency
- Other Risks
 - Retaining an inventory of obsolete parts for equipment that is scheduled to be replaced
 - Vendor support for spare parts is becoming scarce or non reliable
- Replacement Backlogs
 - Would continue to keep obsolete and aging equipment in service thus affecting reliability

Other possible constraints

- Labor constraints can be remedied by using contract design and construction at a greater cost
- Outage constraints can be remedied through the efficient use of work planners and schedulers.

Note: This implementation plan is a replacement program with the optimal funding, staffing resources, and outage availability to best mitigate risks identified in the strategy. These numbers are not aligned with the currently constrained IPR budget. Each sustain program is under review to determine a revised implementation plan that will align with capital budget availability, priorities, and resource constraints. This review will be complete by March 2012.

Executive Summary

What equipment is covered?

Strategic environment & drivers

Strategies

Process improvements

Equipment Strategies

- Power transformers and reactors
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- Instrument transformers and surge arresters
- Station auxiliary
- Substation bus & structures

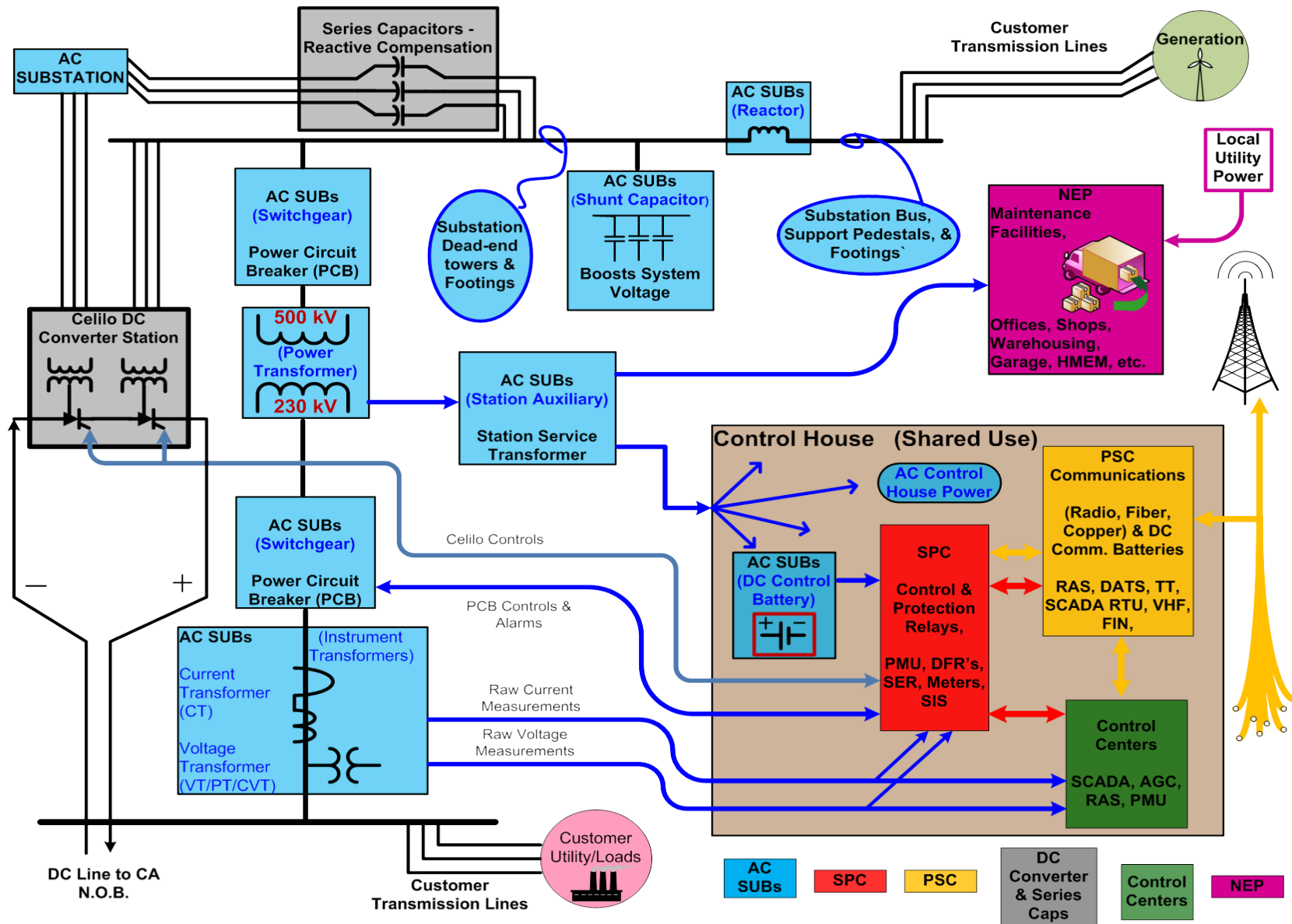
What will it cost?

Program Accomplishments FY10 & FY11

BPA's Alternating Current (AC) Substation Assets

- There are approximately 250 alternating current (AC) Substations on the BPA system.
 - Over 50 of the 250 substations operate at 500 kV
- Substation assets facilitate the efficient transfer of power from source to load and protect the circuits delivering power including transmission lines.
- Substation equipment operates at voltages ranging from 120 V to 500 kV.
 - Substations that interconnect multiple utilities, generators, or serve to transfer power are considered “Network Facilities” – typical network operating voltages are 115 kV – 500 kV
 - Substations that serve radial utility loads are “Delivery Facilities” – delivery voltages range from 4160V up to 230 kV, the vast majority deliver power from 12.5 kV to 115 kV
- Per a benchmarking study conducted by 1st Quartile in May 2011
 - BPA's substations are older than most other surveyed utility's substations
 - Overall capital spending at BPA (activity-based) is lower than average, and our replacement rate is low in comparison to those other utilities

AC Substation Asset Overview



→ What equipment is covered?

Criteria for Asset Replacement

- **Asset Condition:** The physical condition of a piece of equipment, structure, material, or sub-component and its ability to perform its designed task or function regardless of its criticality or position on the power system. The condition rating for an AC substation component (electrical equipment, structure, or material) includes “obsolescence” which considers the ability to maintain the equipment due to workforce obsolescence, lack of spare parts, compatibility of operating systems (i.e., software, control hardware), and manufacturer design flaws.
- **Upgrade:** While most AC substation assets will be replaced as they reach the end of their life due to poor physical condition and/or obsolescence, some equipment will need to be replaced prior to end of life. AC asset upgrades are driven by transmission system changes that render the equipment inadequate or obsolete in terms of the new system operating requirements. Most common are switchgear, either replaced or modified, to meet increased system fault current (fault duty) requirements. The “upgrade” shall provide equipment with a new, higher rating that will meet the changed system operating requirements.
- **Transmissions Priority Ranking Criteria:** A methodology developed by BPA to assess and rank the overall criticality of a substation or transmission line in support of: Asset Management; Workload Planning; System Restoration Plans; Line & Equipment Maintenance; and Seismic/Hazard Mitigation Measures.
- **Asset Risk:** The assessment of equipment or facility likelihood and consequence of failure, obsolescence, inadequacy, health/safety risk, etc.

AC Substation Equipment Types

BPA operates approximately 27,000 major (serial numbered) pieces of high voltage electrical outdoor substation equipment and another 5,000 with limited attribute data. The AC Substations sustain program assets include the following quantities in service:

1. Power Transformers (679), Reactors (750), and Fuses(1,620). Power Transformers facilitate utility and generation points of interconnection and power transfer; Reactors control voltage and current to prevent damage to other equipment and for safety.
2. Switchgear – Power circuit breakers(1,869), Circuit switchers(222) & Disconnects (6,715). Power Circuit Breakers (PCB) and Circuit Switchers (CS) protect high voltage substation equipment from damage during system disturbances and provide rapid clearing of system faults to maintain service. Disconnect switches provide isolation for maintenance and system operating purposes.
3. Shunt Capacitors and Current Limiting Reactors for capacitors (232 groups). Shunt Capacitors – Provide reactive compensation to increases power transfer and boost system voltage.

AC Substation Equipment Types

Continued

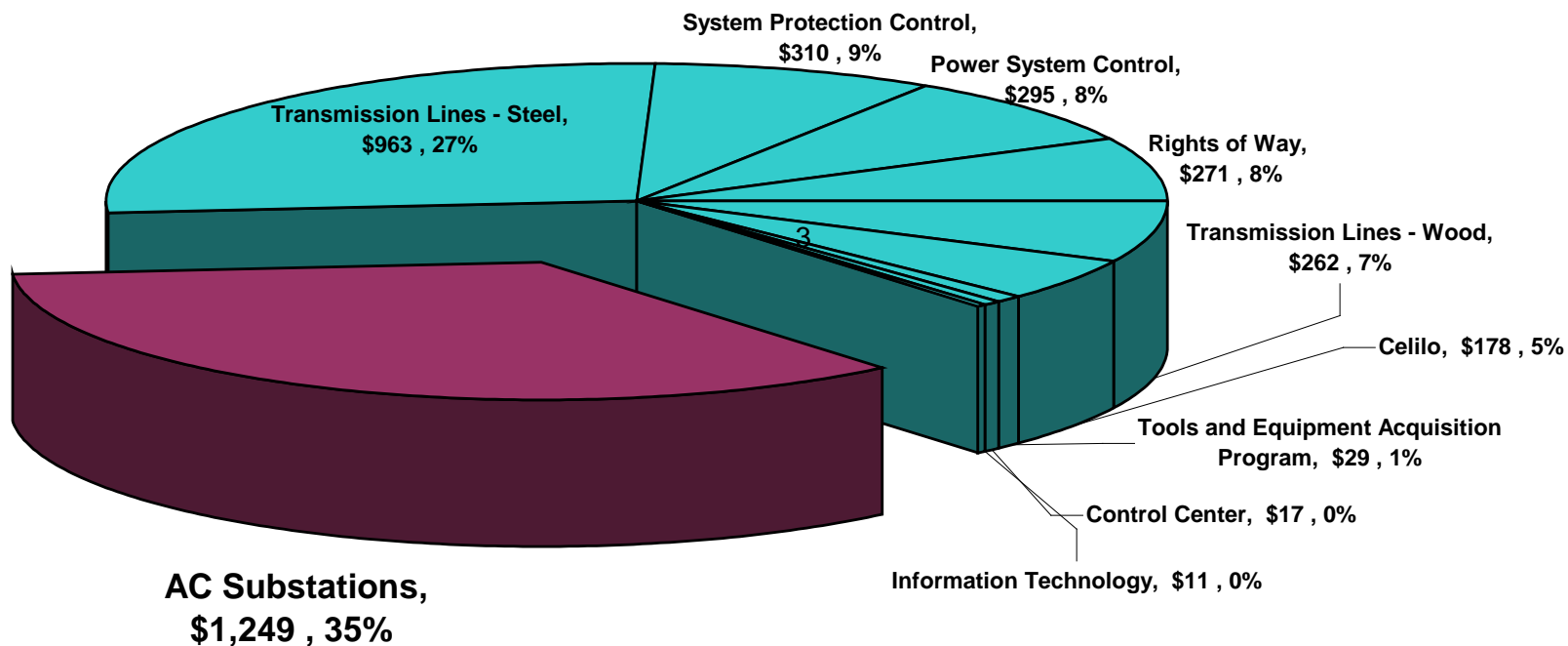
4. Instrument Transformers (6,994) & Surge Arresters (3,511). Instrument Transformers (IT's) measure the voltage or current in the electric power system. These large quantities are transformed and scaled down to a standardized value. Instrument transformers isolate measurement, protection and control circuitry (relays, control, metering, AGC, SCADA, SER, RAS, etc.) from the high voltages and currents being measured. Surge Arresters provide protection for the insulation of high voltage equipment and to some extent transmission lines against potentially harmful system over-voltages. Surge arresters reduce momentary outages (ground faults) due to lightning strikes and switching surges.
5. Station Auxiliary – DC Control batteries (276), Battery Chargers (533), Station Service (SS) Transformers (1,056) & SS Cabling, Engine Generator's (55), Substation grounding. Station auxiliary – Provides operating power for both Indoor and Outdoor substation equipment – includes DC Control Batteries, SS TX's, EG's, SS Cabling, Grounding
6. Substation Bus & Structures – Bus supports, Dead-end towers, Lightning masts, and associated Foundations; Insulators, Bus, and Engine Generator Fuel systems & housing. Substation Bus & Structures – Substation Bus & Insulators - Interconnect HV substation equipment; Dead-end Towers, and high voltage equipment structural Supports – Provide termination points into substations and provide physical separation between equipment and ground and between equipment.

Notes: 1. Non Electric Plant (NEP) excluded from this strategy; 2. Replacement forecasts for All DC Celilo facilities, Static VAR Compensator (SVC) facilities within Keeler, Marion, and Rogue substations & Series capacitor facilities within other stations are covered in the DC Asset Strategy. 3. This strategy does include statistical data for equipment in the DC facilities such as transformers, capacitors, instrument transformers, etc. for comparison of asset demographics and for maintenances practices.

Transmission Net Plant

**Transmission Sustain Programs
Historical Investment After Depreciation
as of Sept. 30, 2011**
(in millions)

Total Book Value is \$ 3,585 million



Executive Summary

What equipment is covered?

 **Strategic environment & drivers**

Strategies

Process improvements

Equipment Strategies

- Power transformers and reactors
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What will it cost?

Program Accomplishments FY10 & FY11

Products and Services

Customers and Stakeholders Served

- Network Transmission Customers – Utilities (Public & Investor owned) & Generators (Independent Power Producers – IPP's & Federal Hydro)
- Delivery Customers – Small utilities (public), small IPP's (co-generation), Tribal PUD
- BPA Internal – System Protection Control (SPC), Power System Communications (PSC), Substation Operations, Substation Maintenance, Billing, Non Electric Plant (NEP) Facilities, Energy Efficiency; Environment, Fish & Wildlife

Products and Services

Enables {

- Network Services: AC sustain enables interconnection/transfer Service (IOU's, PUD's)
- Generation Integration: (Hydro, Wind, Thermal, Coal, Co-Generation)
- Delivery Service: Radial service - Public utilities, small investor owned utilities (IOU's) (load service)

Direct Products {

- Reactive Compensation: VAR Support, ATC, OTC
- Measurement & Indication (voltage & current) for System Protection & Control, Revenue Metering, Control Area & Interchange Scheduling, AGC
- Spare power transformer support for regional customers, and nationally - member of EEI (Edison Electric Institute) STEP Program since 2006

Standards that Apply

Reporting requirements are increasing for substation equipment maintenance, equipment failure tracking/trending, and equipment ratings (thermal/continuous). AC substation assets must be managed to meet a variety of standards and requirements:

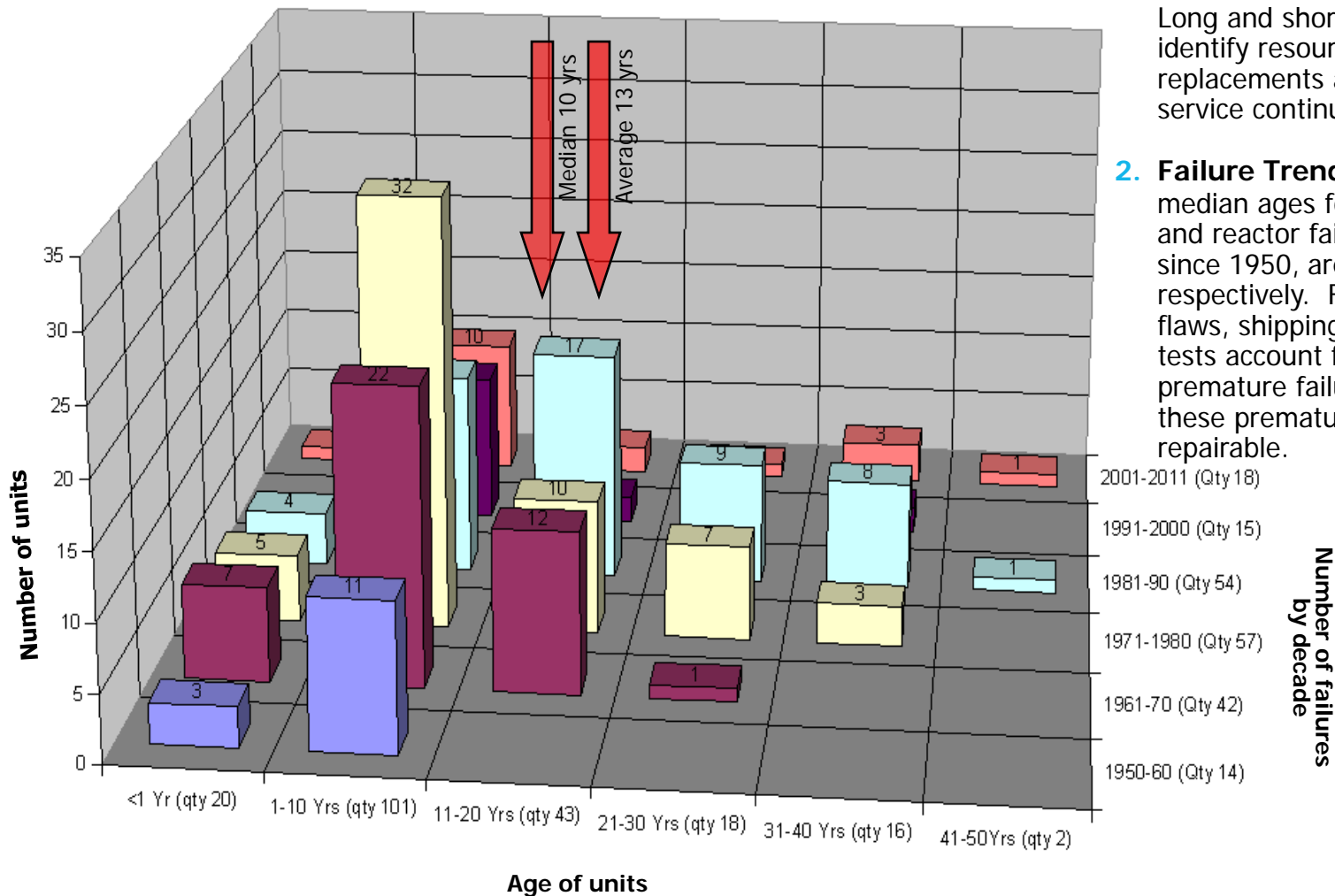
- The Western Electric Coordinating Council (WECC) and North American Electric Reliability Corporation (NERC) require BPA to report the actual cause for any reportable line wherein BPA is the designated “Transmission Owner (TO).”(WECC Paths West of Hatwai, COI , North of John Day cutplane, COI/PDCI – North of John Day cutplane)
- WECC - PRC-STD-005-1 – Transmission Maintenance (Power Transformers, Circuit Breakers, Regulators, Shunt Capacitors, Shunt Reactors, and Tertiary Reactors)
- WECC - TOP-STD-007-0 – Operating Transfer Capability (West of Cascades – North, West of Cascades – South)
- NERC – FAC (Facility Rating) and PRC-005, 011, 017 (Battery Maintenance) PRC-STD-005-1 (Transmission Maintenance)
- NEPA – Toxic Substances Control Act (TSCA) – PCB containing equipment (SF6 Gas Reporting & Oil leak mitigation – reporting) requirements
- ANSI/IEEE/IEC/ASTM – HV Equipment ratings and application standards, Structures & supports - Civil & Structural standards including seismic
- NESC/OSHA – Safety
- OB-19 Significant Equipment, and other Operating Bulletins affecting the operation of HV equipment
- BPA system performance metrics and targets

Strategic Drivers

- Manufacturing practices and vendor support are changing and the new practices are forcing electric utility and transmission providers to replace equipment earlier than in the past.
 - Newer equipment has shorter life span
 - Long term vendor support is becoming increasingly limited which affects spare parts availability and cost
 - System capacity is increasing while equipment operating margins are decreasing due to age and/or effective life-cycle
 - Technology obsolescence
 - Workforce obsolescence
- Historically, BPA has replaced AC substation equipment based primarily on failures or failure rates.
- HV manufacturing practices for transformers and breakers show a trend toward decreased equipment operating margins, decreased lifespan, and decreased vendor support (parts & service) for older equipment.
- Approximately 85% of breakers are replaced today due to the inability to obtain spare parts combined with excessive cost or unacceptable lead times for spare parts
- Transmission will continue to promote standardization in the purchase of new substation equipment that meets system-operating requirements, which will balance warehousing costs of spare parts while continuing to support maintenance activities. This effort also helps mitigate spare parts unavailability and lack of vendor support of obsolete equipment.
 - Power circuit breakers and disconnect switch ratings have been standardized at various continuous current ratings that allow the greatest flexibility in using the equipment at almost any location on the system. This helps reduce the number of spare parts.
 - Instrument transformers and surge arrester ratings have also been standardized, to the extent possible, to reduce the number of spare units needed for both system expansions and emergencies.

Equipment Life-cycles

Power transformers and reactors shown by Age during failure and Number of failures per decade for the past 60 years. Total Installed (639), total failed (200).



1. Life Expectancy: Average expected life of a transformer is 45-50 years. Nearly half of BPA's power transformers are 40 years and older. Long and short-term strategies will identify resources needed for replacements and spares needed for service continuity.

2. Failure Trends: The average and median ages for recorded transformer and reactor failures for all voltages, since 1950, are 13 years and 10 years respectively. Failures due to design flaws, shipping damage, failed factory tests account for most of the premature failures. The majority of these premature failures were repairable.

Increasing Demands on AC Substation Assets

- A key Transmission asset management goal is to make fuller, more optimal use of existing system capacity. Among other impacts, this goal may lead to:
 - Tighter margins on reliability and availability and ultimately equipment performance
 - Reduced tolerance for equipment failure
 - Reduced outage availability for maintenance
- Loads are projected to continue growing, putting increased demands on existing equipment in terms of loading (thermal ratings) and decreased outage availability for maintenance or system disturbances (contingencies).
- Integration of generation, such as wind generation, are also growing. Existing substation equipment can accommodate, to some extent, integration of key wind and other generation resources. However, using up existing system capacity tends to:
 - Put increased demand on equipment (thermal and short circuit ratings)
 - Reduce operating margins that allow for system contingencies, and
 - Reduce maintenance and operational flexibility
- Generators are frequently connected radially making terminal equipment and line outages for maintenance harder to obtain – availability constraints.

Factors

- The Substation Bus & Structures is a new AC sustain asset group that requires development of an inspection, maintenance, and replacement program. RCM and the Substation Maintenance and High Voltage Engineering group will develop criteria and help implement inspection and maintenance procedures as well as implementing data templates in TAS/Cascade for tracking asset condition, maintenance and resource requirements.
- The loss of skilled/experienced workers (maintenance, technical support, parts specialists) through retirement and attrition is a major factor in maintaining older equipment. The effect is compounded by reduced vendor support (parts, service, training).
- There is an increasing demand to monitor, test, and report on equipment condition, both for regulatory and program strategy purposes. Cascade is the data repository which is the source for regulatory reporting. Data contained in Cascade is also in the program strategy development and evaluation.

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- Power transformers and reactors
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What will it cost?

Program Accomplishments FY10 & FY11

Transmission Asset Management (TAM) Goals

Applicable to AC Substation assets

Goals for sustaining transmission

Goals

- G9** Information on asset attributes (condition , performance, costs) is complete, accurate and readily accessible.
- G10** Assets are proactively maintained and replaced
- Maintenance, replacements and sparing planning is integrated
 - Priority is given to critical assets at greatest risk of failure or noncompliance
 - Reliability, availability, and other standards are met at least life-cycle cost
- G11** Maintenance is reliability centered (condition-based)

Strategic initiatives

- I-12.** Establish processes, procedures, controls, roles & responsibilities to ensure nameplate, condition assessment, outage history, maintenance costs and other asset information is accurate, complete, and readily accessible via the Transmission Asset Register (implementation to be addressed through the IPPI projects) (G9)
- I-14.** Prioritize and manage maintenance and replacement backlogs to sustainable levels (target dates set in life-cycle strategies for each sustain program) (G10, G11)
- I-15.** Develop and implement a process that ensures replacement and maintenance actions result in no more than X% of critical assets at high risk of failure (target percents and target dates sit in life-cycle strategies for each sustain program) (G10, G11)
- I-16.** Develop and implement sparing strategies to assure a supply of critical parts is geographically situated to enable timely restoration of service (G10)
- I-17.** Establish condition-based maintenance standards and implement reliability-centered maintenance as each asset class is added to TAS (G11)

Process Improvement

Transmission Asset Management Goal G9

Information on asset attributes (condition , performance, costs) is complete, accurate and readily accessible.

Strategic Initiative I-12: **Establish processes, procedures, controls, roles & responsibilities to ensure nameplate, condition assessment, outage history, maintenance costs and other asset information is accurate, complete, and readily accessible via the Transmission Asset Register (implementation to be addressed through the IPPI projects) (G9)**

TAS data repository

- Asset demographics – equipment category, type, manufacturer and model, location, ownership, licensing and age
- Condition – maintenance and inspection history, inspection and test results, trouble reports
- Performance - failure history and benchmarks, maintenance and material costs to be factored into life-cycle cost
- Is the official source(s) of asset information
- Provides ready access to the information with an intuitive interface
- Ensures data collection, validation and entry processes are efficient and timely
- Data is collected and entered close to their origin which reduces the chance of error

Asset information is assessed on a recurring basis so that only essential data is collected and unnecessary data is not.

Data requirements are determined by subject matter experts to help assess the following:

- Identify the agency decisions that require asset information
- Identify the information that is needed to supply the decisions
- Specify the data requirements
- Determine data sources
- Standardize the data definitions

Actions to meet TAM Goal G9: Creating the Repository (TAS)

A complete and integrated life cycle asset strategy must include three core elements: (1) equipment condition (health), (2) operating cost (labor & materials associated with operation and maintenance), and (3) criticality (system impact) as it relates to reliability and availability.

The core of condition assessment data will be based on the continual, timely, and accurate recording of data using the following methods:

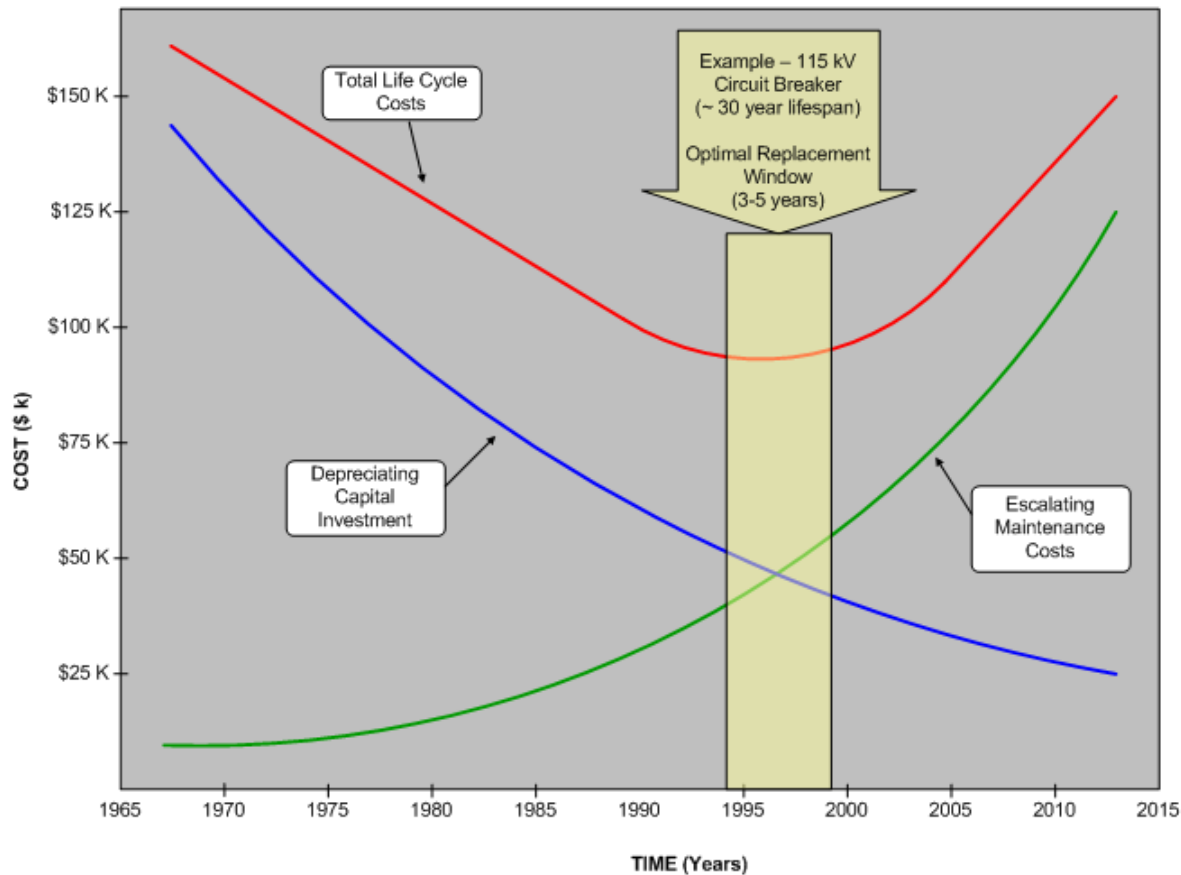
- Operator Patrol Inspection – Performed by Substation Operators periodically or in response to trouble. Perform visual inspection of equipment and record counters, gauges, oil leaks, damage, position, etc. that may be used to trigger a condition based maintenance action.
- Monitoring - Monitoring provides raw data on the duty and stresses seen by equipment and their subsystems (insulation, mechanisms, relays). Continual online monitoring is performed on a limited basis on high value equipment where risk of loss is high and benefits warrant the added cost. Periodic monitoring is performed on an “as needed” basis when condition indicators warrant closer and more frequent monitoring. Monitoring can be improved with the use of newer technology like “smart relays” that can replace older relay technology and facilitate the gathering of raw data (operating signatures and duty severity) particularly for critical breakers and transformers.
- Maintenance – Record “Corrective” maintenance or “Preventative” maintenance as prescribed and performed in the “Preventative Maintenance Guides” (PMGs) which lists maintenance triggers based on equipment operating performance, maintenance history, and failure trends, i.e. RCM principles.
- Analyze – Inspection, maintenance, monitored data must be collected in a repository which allows ready access. CASCADE will be the key repository for condition data collection. The data will be analyzed to identify both maintenance requirements and in part for the replacement or life-cycle strategies.
- Adjust – Adjust the triggers and values recorded based on the analysis of the data collected.

Actions to meet TAM Goal G9: CASCADE implementation

<p>Objective: Asset attributes – Performance data: Includes outage history and duty severity data from other sources that is integrated or linked with CASCADE and aligns with equipment maintenance and cost history.</p>	
<p>Measures:</p>	<p>Target:</p>
<p>Relevant system operating data from SCADA, PI, OARS, SER, DIR, Doble-DTA, TOA, etc. are integrated or linked with CASCADE. This include (fault magnitudes, overvoltages) for critical transformers and breakers.</p>	
<p>345 – 500kV transformer load (MW) and temperature data (peak load and temp, annual trends) are integrated or linked with CASCADE.</p>	<p><u>4th QTR 2013</u>, Complete load and temperature data integration for 50% of all 345- 500 kV transformers.</p>
<p>Circuit breaker fault current (I^2t and cumulative I^2t) is collected from smart relays where they currently exist and integrated into CASCDE.</p>	<p><u>4th QTR 2013</u>, Complete fault magnitude data integration for 10% - of most critical 500 kV circuit breakers.</p>

Actions to meet TAM Goal G10: Life-cycle strategies

Assets are proactively maintained and replaced for optimum risk management (resources and reliability)



- CASCADE provides full integration and collection of pertinent risk and condition data.
- RCM principles are continually applied and refined as the asset repository (TAS) is populated with equipment history.
- Life-cycle analysis - algorithms are developed and implemented in CASCADE and refined as needed to integrate new equipment technology and changes in risk and condition factors.

Actions to meet TAM Goal G10: Continually refine tools and data

Assets are proactively maintained and replaced for optimum risk management (resources and reliability)

- Continually refine and update analysis tools and source data. Where value is added, incorporate new data sources as monitoring technology advances and comes more affordable
- Eliminate or discontinue collecting data that consumes resources but adds little or no value since it doesn't contribute to condition based maintenance.
- A capital replacement forecast spreadsheet has been developed which prioritizes the next 10 years of replacements for all six of the AC Substation programs. This helps to identify resource requirements and spare equipment/parts requirements until equipment is forecasted to be replaced.

Actions to meet TAM Goal G10:

Prioritizing and managing maintenance and replacement backlogs

<p>Objective: Using CASCADE - analyze maintenance activities resulting from both preventative (currently time based) and corrective (driven by failures), inspections and reparability (parts & service) to establish maintenance schedules and manage backlogs.</p>	
<p>Measures:</p>	<p>Target:</p>
<p>Scheduled preventative maintenance is deferred for equipment planned to be replaced as permitted under WECC criteria.</p>	<p><u>4th QTR 2012</u>, Forecasted 2 year maintenance schedules are modified to show reduced maintenance for 50% of planned breaker replacements.</p>
<p>Develop analytical criteria/algorithms to begin implementing “life-cycle” maintenance and replacement strategies for high risk equipment. Develop objective, consistent, and repeatable methods that utilize the major data sources – condition, risk, material cost, and labor costs.</p>	<p><u>4th QTR 2012</u>, Preliminary maintenance algorithms are entered into CASCADE and maintenance priorities are tested using available CASCADE data.</p>

Actions to meet TAM Goal G10: Equipment criticality

- Critical AC substation equipment is at low risk of failure.
 - A Low risk of failure constitutes a Condition rating of “good, fine or fair” and a high risk of failure constitutes an “impaired or poor” condition rating.
 - Critical AC substation equipment generally consist of all power transformers and reactors, capacitors; a majority of power circuit breakers and a small portion of circuit switchers; a large portion of disconnect switches, primary station service power sources, and all DC control batteries.
- Critical equipment is determined by Transmissions priority ranking criteria and other system risk factors. Transmissions priority ranking criteria for substations and lines assigns a ranking based on the overall criticality of the entire substation or line.
 - There are minor limitations to this approach since it does not take into consideration contingencies and variations in criticality within the substation or line.
- System operating and performance (reliability and circuit availability) criteria is developed or identified for critical AC equipment. These include such factors as SAIFI and SAIDI, ATC, OTC, and radial service requirements that define target service levels.

System Performance Measures and Targets

Applicable to AC Substation assets TAM Goal G10

Measures:	Target:
<p><u>Category A - Transmission Line Reliability & Availability:</u></p> <p>AC substation terminal equipment failures or maintenance outages affecting transmission line automatic or planned (maintenance) line outages.</p> <ul style="list-style-type: none"> – Provide success indicators for minimizing unplanned line outages due to substation equipment (terminal equipment) failures. (SAIFI & SAIDI for lines) – Provide success indicators for managing substation equipment maintenance outages to minimize planned line outages. 	<p>See System Performance Measures & Targets on next slide</p> <p><u>(Category A)</u></p>
<p><u>Category B – Circuit Availability (Transmission Curtailment):</u></p> <p>AC substation equipment <u>failures</u> or <u>maintenance</u> outages affecting transmission path ATC, OTC ratings.</p> <ul style="list-style-type: none"> – Provide success indicators for minimizing unplanned substation equipment outages (failures) resulting in a reduction of available or operating transmission capacity. – Provide success indicators for managing substation equipment maintenance outages to minimize possible reductions in transmission availability 	<p>TBD – ATC/OTC Targets</p> <p><u>(Category B)</u></p>
<p><u>Category C – Circuit Availability (Load Shedding):</u></p> <p>AC substation equipment <u>failures</u> or <u>maintenance</u> outages affecting load service.</p> <ul style="list-style-type: none"> – Provide success indicators for minimizing unplanned substation equipment outages (failures) resulting in load loss, service disruption. – Provide success indicators for managing substation equipment maintenance outages to minimize load loss, service disruption. 	<p>TBD – Load Service Targets</p> <p><u>(Category C)</u></p>

System Performance Measures and Targets TAM Goal G10

Category A - Transmission Line Reliability & Availability Applicable to AC Substation Assets

		System Performance Measures	End-stage Targets
Reliability	→	<p>System Average Interruption Duration Index (SAIDI) - Average duration of automatic outage minutes by BPA line category.</p> <p>Provides an indication of BPA's success at minimizing the duration of unplanned transmission line outages</p>	<p>No control chart violations per year for line importance categories 1-2</p> <p>No more than 1 control chart violation per year for line importance categories 3-4</p>
	→	<p>System Average Interruption Frequency Index (SAIFI) - Average number of automatic outages by BPA line category.</p> <p>Provides an indication of BPA's success at minimizing the number of unplanned transmission line outages</p>	<p>No control violations per year for line importance categories 1-2</p> <p>No more than 1 control chart violation per year for line importance categories 3-4</p>
		<p>Report of number of outages to transmission lines of all voltage levels caused by vegetation growing into the conductor or within flashover distance to the conductor. (Relates to vegetation growing from either inside or outside the BPA right-of-way)</p>	<p>No outages to transmission lines of all voltage levels caused by vegetation growth</p>
Availability		<p>System Operating Limits (SOL) for BPA Paths, Interties, & Flowgates</p> <p>Number of minutes that actual path flows are near, at or above System Operating Limits. Indicates congested areas for which capacity expansion may merit consideration.</p>	<p>No end-stage target will be set for this metric during this planning cycle</p>
	→	<p>Availability for service of BPA's most important transmission lines (Category 1 and 2)</p>	<p>BPA's most important transmission lines (Category 1 and 2) are available for service at least 98.0% of the time</p>
	→	<p>Availability for service of BPA's less important transmission lines (Category 3 and 4)</p>	<p>BPA's Category 3 and 4 lines are available for service at least XX.X% of the time. Target being determined</p>

Actions to meet TAM Goal G10: Sparing strategies

Strategic Initiative I-16: Develop and implement sparing strategies to assure a supply of critical parts is geographically situated to enable timely restoration of service.

<p>Objective: Develop new and revise existing maintenance standards such as the <i>Preventative Maintenance Guides</i> (PMG's) and <i>Substation Maintenance Standards and Guides</i> to shift from time based to reliability centered maintenance (RCM) as applicable. (Relates to G11)</p>	
<p>Measures:</p>	<p>Target:</p>
<p>Sparing strategies for 500 kV transformers are completed and approved by the CAB.</p>	<p><u>4th QTR 2012</u></p>
<p>Sparing strategies for 69 kV – 345 kV transformers are completed and approved by the CAB.</p>	<p><u>2nd QTR 2013</u></p>
<p>Sparing strategies 230 kV & 500 kV reactors are completed and approved by the CAB.</p>	<p><u>4th QTR 2013</u></p>
<p>Emergency spare inventory is evaluated on all other equipment groups.</p>	<p><u>ANNUALLY</u></p>

Transmission Asset Management Goal G11

Strategic Initiative I-17: Establish condition-based maintenance standards and implement reliability-centered maintenance as each asset class is added to TAS (G11)

Strategy considerations:

- In order to modify existing time-based maintenance practices to RCM, a minimum amount of historical data must be captured and analyzed.
- Equipment health algorithms can be implemented and tested in Cascade based on collected maintenance and inspection data.
- BPA must continue to meet existing and new WECC/NERC maintenance requirements while transitioning from traditional time based maintenance to a condition based maintenance approach based on RCM principles.

Actions to meet Goal G11: “Maintain vs. Replace” Strategies

Operate to Failure Considerations – Criticality and risk objectives need to take into consideration equipment functionality in making “maintain vs. replace” decisions. This includes providing criteria, in terms of reliability, to permit functional failure to varying degrees for each equipment type. Having a strategy which attempts to completely avoid all in service failures, i.e. striving for all assets to be “good” condition - is not a realistic or financially attainable goal.

- **Failure Definition** – Failure can have many definitions and is defined here for the context of this strategy. Failure means the equipment or component is no longer performing it’s function as designed and does not necessarily imply destructive or irreparable failure. The goals set forth in this strategy are focused on managing risk and resources by allowing “functional” failure in some instances, but still planning for the replacement/retirement prior to destructive failure and to levelize resource requirements.
- The “operate to failure” premise is intended to address the differences in equipment maintenance, and associated repair/replace strategies. Some equipment lends itself to repair/refurbishment after functional failure and others do not.
- Substation equipment that is repairable tends to have moving parts, is made up of subsystems (i.e. interrupters, operating mechanisms, load tap changers, resealable insulation systems etc.) and tend to be high cost. Equipment that is not repairable tends to have few if any moving parts or subsystems and have insulation systems that are permanently sealed and tend to be lower cost.

Actions to meet Goal G11: “Maintain vs. Replace” Strategies

Operate to failure guideline – Building on the “operate to failure” considerations from the previous slide the following outline provides the predictors for the types of equipment that may be permitted to fail while in service. This criteria should guide the level of effort for condition assessments in terms of resources to expend and types of data to be collected for risk and condition factors.

Operate to Failure/Near Failure Equipment Characteristics

- Equipment with few moving parts and little to no maintenance can be performed
- Condition monitoring relies mainly on inspections and infrequent interval testing
- Online monitoring is cost prohibitive in most cases (monitor may cost more than the equipment and measurement may not be feasible)
- Replacement predictions rely on long term failure trend data & age for the entire unit and associated degradation factors (insulation life expectancy)

Do NOT Operate to Failure Equipment Characteristics

- Mainly equipment with many moving parts – inherently maintenance intensive
- Built in bypass capability in most stations for maintenance
- Failure predictors rely on recordable maintenance trend data/monitoring, duty severity, component failure rates
- Replacement predictors rely on:
 - Availability of spare parts
 - Ability to rebuild/refurbish
 - Equipment life cycle costs, component & subsystem performance

Actions to meet Goal G11: Implementing RCM

The following transition periods are based on existing maintenance intervals and the estimated time needed to populate the CASCADE data repository with sufficient data to make well-guided transitions.

<p>Objective: Develop new and revise existing maintenance standards such as <i>Substation Maintenance Standards and Guides</i> to shift from time based to Reliability Centered Maintenance (RCM) as applicable and outlined in the <i>Preventative Maintenance Guides</i> (PMG's). (Relates to G11)</p>	
Measures:	Target:
Timeline by which PMG's for RCM methods are approved for power transformers, grounding transformers, oil filled reactors, instrument transformers, disconnect switches (excluding operators), station service transformers.	<p><u>Target:4th QTR 2012:</u> Preliminary RCM PMG's are in place for all these equipment types.</p> <p><u>Target 2017:</u> Final Approved RCM PMG's are in place for all these equipment types</p>
3-5 year transitions: Power circuit breakers & circuit switchers (operators and mechanisms), shunt capacitors, disconnect switch motor operators, station service transformers, surge arresters.	<p><u>Interim Target:4th QTR 2012,</u> Implement/test preliminary RCM maintenance for "light service duty" SF6 Gas breakers.</p> <p><u>Target 2015:</u> Full RCM practices</p>
2-4 year transitions: DC control batteries, battery chargers, <u>control circuits</u> for power circuit breaker and circuit switcher, engine generators.	<p><u>1st QTR 2013:</u> Begin implementing full RCM practices</p>

Actions to meet Goal G11: Implementing RCM

- Subject matter experts (SME's) in RCM, technical services groups, and IT will facilitate integration of pertinent risk and duty severity data into CASCADE, i.e. SCADA, PI, OARS, SER, DIR, Doble-DTA, TOA, etc. type data.
 - This may require additional software tools to integrate or link data from these separate data systems with CASCADE or an expansion/customization of CASCADE.
- SME's will analyze, develop, and select appropriate replacement ranking methods (algorithms) to prioritize replacements and use RCM principles to develop maintenance triggers.
 - Incorporate study results from EPRI, CEATI, KEMA, and other sources as applicable to BPA assets to build algorithms in Cascade.
 - Through BPA's involvement in these outside organizations criteria has been developed to assess asset health and develop algorithms to trigger maintenance, refurbishment or replacement of equipment.
- Maintenance triggers will be adjusted based on the analysis of recorded data and value of work being performed.

Executive Summary

What equipment is covered?

Strategic environment & drivers

Strategies

Process improvements

Equipment Strategies



- Power transformers and reactors
- Switchgear
- Shunt capacitors
- Instrument transformers and surge arresters
- Station auxiliary
- Substation bus & structures

What will it cost?

Program Accomplishments FY10 & FY11

Transformers & Reactors: Asset Criticality

- Power transformers convert power (voltage and current) to maximize the efficiency in moving and delivering power between generation sources and load centers. Transformers facilitate the transfer of power between substations, utilities, and generators that operate at different voltages.
- Reactors serve two primary roles: 1- Controlling potentially harmful system overvoltages on long transmission lines, particularly during light load conditions; 2 - Reducing system fault currents.
- Criticality is determined by the combination of 1- Substation and Transmission Line priority ranking criteria, 2-radial only service, and 3-various contingencies affecting ATC/OTC and RAS schemes.
- All 500 kV, 345 kV, and many 230 kV power transformers are considered critical equipment. This includes all 500 kV reactors used for voltage control and fault reduction.
- Criticality is used in risk assessments and in prioritizing replacement and maintenance work.
- Per a study conducted by 1st Quartile in May 2011 BPA's transformers are generally older than other utilities.

Transformer & Reactor: Performance Objectives

Power Transformer Performance Objectives

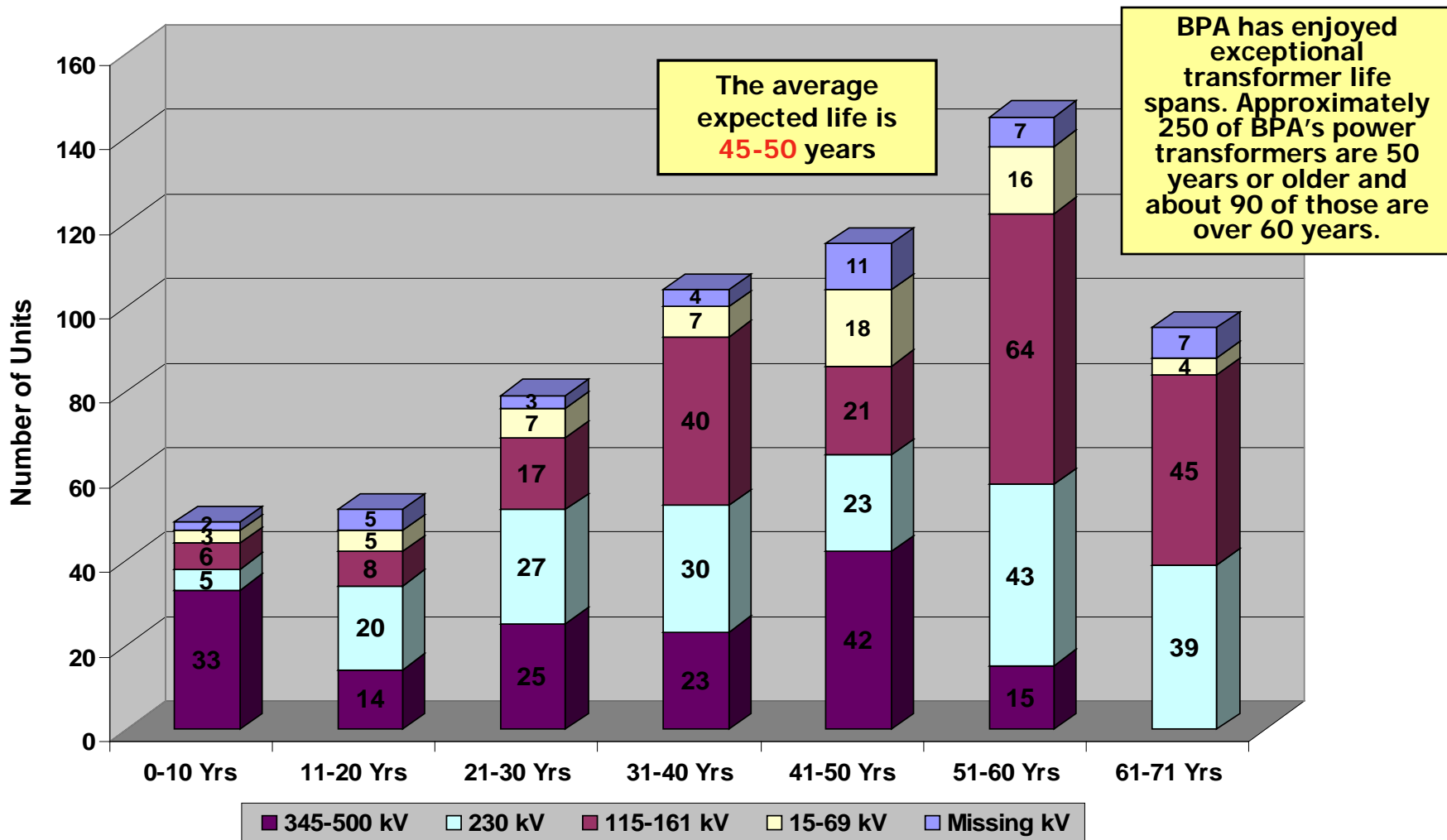
- **Performance Objective:** Ensure that equipment and procedures are in place that allow service restoration to be completed within targeted time limits.
 - **Measure(s):**
 - Service restoration performance
 - **End-Stage Target(s):**
 - Spare transformer strategies for 500 kV have been approved by the CAB **Q4, FY 2012**, and for 69-345kV by **Q2, FY 2013**. Transformers are procured and deployed consistent with the strategy. The number and location of spares is included in this strategy.
- In the event of a transformer failure
- Emergency mobile transformers (trailer mounted) are energized 24 to 100 hours after notification
 - Non-mobile spares are energized within 24 hours for sites with a jack-bus to a maximum of 750 hours for sites with no jack-bus or no spare on site.

Reactor Performance Objectives

- **Performance Objective:** Ensure that equipment and procedures are in place that allow service restoration to be completed within targeted time limits.
 - **Measure(s):**
 - Service restoration performance
 - **End-Stage Target(s):**
 - By 4th QTR 2013 loss of reactor contingency plans, including spares strategy, are completed. This will include the number and location of spares for shunt (oil filled) reactors and contingency options for loss of both shunt and series (air core) reactors .

Transformer & Reactor: Age Demographics

Power Transformers, Grounding Transformers and Reactors
by Age and Voltage Classification



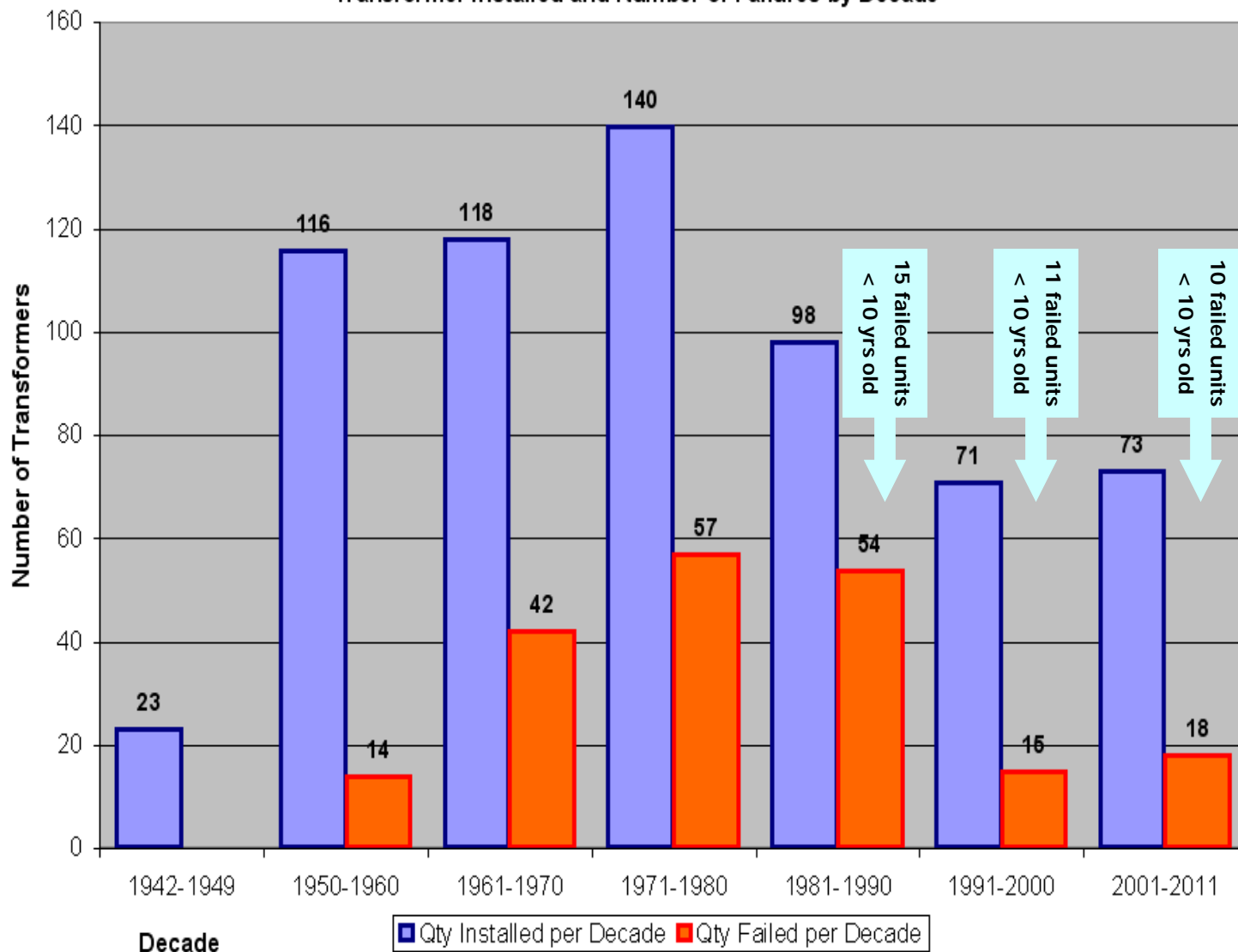
Transformer & Reactor: Failure Factors

Transformer failure history shows that BPA's mean time between failures (MTBF) for 500 kV auto transformers is 1 failure every 18 months. This is a statistical calculation that spans almost 5 decades and 2917 transformer operating years. In 2009 when the study was completed 27 auto transformers had failed with 18 being replaced and 9 being repaired. Since that time the numbers have increased to 29 failures with 20 being replaced and still only 9 being repaired.

- Transformers with bushing and load tap changer failures typically do not require complete transformer replacement. However, both of these repairs are limited by the availability of vendor support, the ability to stock adequate quantities of replacement bushings in inventory, and the special facilities, tools, and skills required of BPA staff to carry out these repairs.
- Transformers with winding or insulation failures are frequently deemed not repairable. In many cases the repair and shipping cost are comparable to buying a new transformer.
- Large Power Transformers and reactors tend to be unique in design and trouble indicators can vary widely between units, vendors, and construction. Improvements in monitoring and use of system/equipment event data can assist in evaluating transformer reliability. Power Transformers and Reactors often fail without prior warning.
- Monitoring of system conditions affecting transformer load, duty (stress), and transformer condition data is either severely limited or very decentralized. Improving monitoring practices will become a key component in evaluating transformer reliability to better prepare for eventual failures, minimize system interruptions, and help avoid potential oil spills in sensitive areas.

Transformer & Reactor: Demographics and Performance History

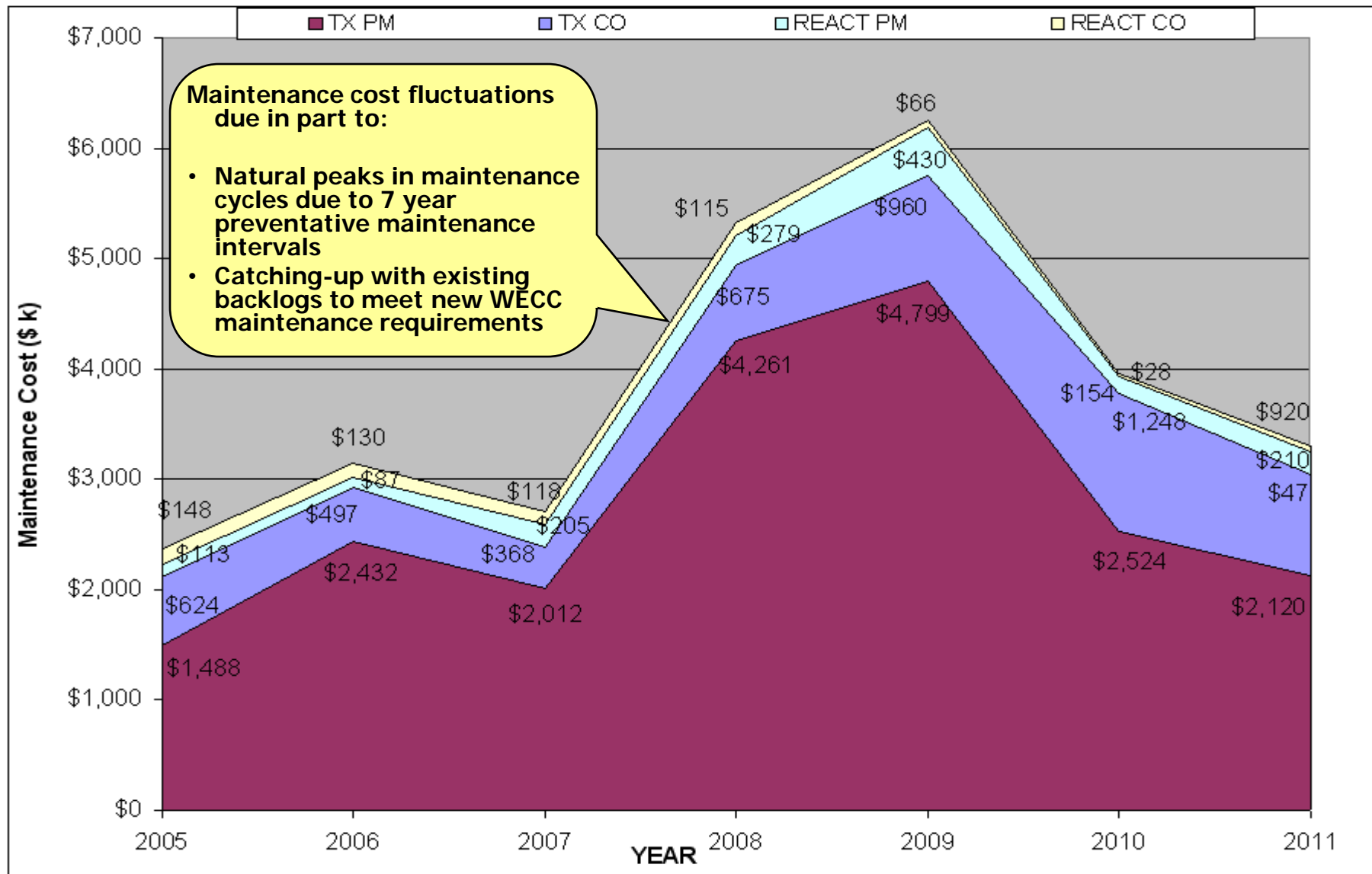
Transformer Installed and Number of Failures by Decade



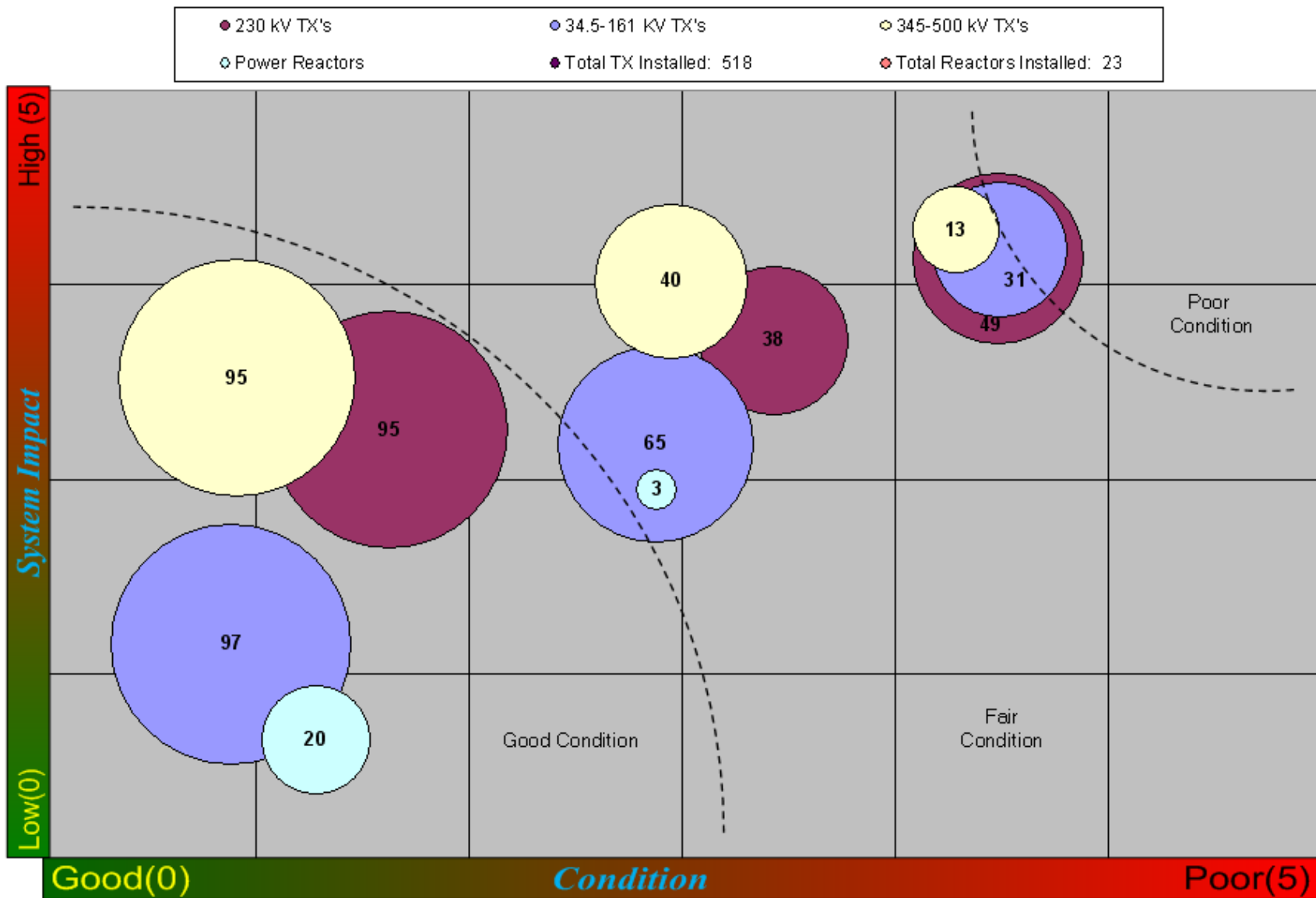
In its roughly 60 year history, BPA has experienced at least 14 power transformer and reactor failures every ten years. Industry asset reports indicate that there will be marked increases in failure rates when the existing assets enter their 5th decade of service.

Detailed data on failures resulting in replacement vs. repair is limited. Some data for 1991-2010 indicates a high percentage of 500 kV transformer failures that were not repairable.

Maintenance Costs– Power Transformers and all Reactors



Transformer & Reactor: Assessing Risks



Transformers & Reactors: Strategy

The Power Transformer and Reactor strategy is focused on four key areas:

- Performance monitoring and data analysis
- Maintenance and Operations approaches
- Equipment standardization
- Maintaining the proper level of spare equipment and parts

Performance - Monitor/Record/Analyze Data

- Parameters to be monitored and recorded:
 - Gas in Oil (GIO), currently very limited online monitoring with “Hydran” or similar monitors
 - Temperature
 - Loading (SCADA, PI)
 - Inspections - recorded via CASCADE Patrol Inspection templates
 - System conditions - Faults (Relay data from Digital Fault Recorders, Future “smart relays”)
 - Corrective maintenance - triggered by equipment failure reports recorded via CASCADE corrective maintenance templates)
 - Preventative maintenance - Both periodic – Annual GIO, and triggered maintenance: preventative maintenance guides (PMG’s) recorded via CASCADE Maintenance templates
- Maintenance data to be recorded (include frequency, maintenance hours, cost)
 - GIO (Annual Test)
 - Load Tap Changer service
 - Bushings - Power Factor testing
 - Oil leak inspection and mitigation
 - Windings – Insulation Power Factor, Turns Ratio

Transformers & Reactors: Strategy

Maintenance and Operations

Oil filled power reactors are very similar to power transformers in terms of life span, maintenance, and failure predictions albeit they are somewhat simpler in design and construction.

- Maintenance – Maintain the integrity of the transformer insulation system. Due to relatively long lead times for replacing and repairing failed transformers the key to this strategy is maintenance (preventative & corrective), data gathering (inspect, test, monitor) and maintaining spares.
- Operations – Manage load levels below thermal limits to lengthen transformer life. Protect against faults (relaying) and surges (MOV's) to minimize internal mechanical and electrical damage.

Transformers & Reactors: Strategy

Equipment standardization

- For large Power Transformers (230 kV – 500kV) “Strategic Sourcing” is securing Master Agreements and Compliance Contracts to optimize cost and delivery time. Power Transformer sizes have been standardized at 433MVA (1-Phase) for 500 kV and 300MVA (3-phase) for 230 kV. This standardization has allowed BPA to enter into a long term requirements contract reducing delivery time from average 24-30 months down to 8-20 months. When making replacements, transformers will be low loss, low noise, high internal fault capability transformers. They should be similar in design for efficiency of support and redundancy across the system.
- Large Power Transformers and reactors tend to be unique in design and trouble indicators can vary widely between units, vendors, and construction. Improvements in monitoring and use of system/equipment event data can improve predictions in transformer reliability. Power Transformers and Reactors often fail without prior warning.

Spare Equipment and Parts

- Spare transformer strategies need to be updated and revised to address the current risk criteria. These spare transformers are necessary to maintain existing transformers, ensure transportation of spare transformers does not affect BPA's ability to continue reliable service for transformer failures, and mitigates the risk associated with managing an aging transformer population.
- Installing fourth phase spare transformers would be in-line with practices at other major utilities including TVA. It will ensure that as the transmission system becomes more and more congested and outages become difficult to take, that maintenance can still be performed by placing the fourth phase spare transformer in-service.

Transformers & Reactors: Strategy

Purchasing and Spare Equipment Policies

- The current number of spare transformers for operating voltages 230 kV and below is one spare for every 20 banks (3-phase) in service. The 1:20 ratio of spares is based on historical failure rates, service restoration targets, and industry practices for spares in this voltage range. This ratio allows BPA to cover the failure of two transformers 95% of the time.
- The number of spare 345 kV & 500 kV transformers is risk based and the policy guidelines vary depending on the type of service. Spare units of this size are not determined by a fixed ratio but on system operating risk (ATC/OTC), transportation constraints, generation curtailment, and maintenance requirements.
- In October 2008, a business case was approved to procure 5 additional 500 kV spare transformers. These 5 new transformers are being used to improve transformer bank availability in the event of a failure and also to serve as system spares for banks which do not have an on-site spare transformer.
- The approach for spare transformers has been a subject of much discussion in recent years due to increasing limitations in maintenance outages, limitations in transportation (road & rail), and risk of damage during transportation of large 345 kV & 500 kV spares.
- Spare power transformer support for regional customers, and nationally - member of EEI (Edison Electric Institute) STEP Program since 2006

Transformers & Reactors: Implementation Milestones

Sparing Strategy

- By 4th Qtr 2012 the transformer spare strategy for 500 kV transformers shall be updated and the new strategy approved by the CAB. Approval by ACPRT will be completed by 3rd Qtr 2012.
- By 2nd Qtr 2013 the transformer spare strategy for 69 kV - 345 kV transformers shall be updated and the new strategy approved by the CAB. Approval by ACPRT will be completed by 1st Qtr 2013.
- By 4th Qtr 2013 the 500 kV - 230 kV reactor spare strategy shall be updated and the new strategy approved by the CAB. Approval by ACPRT will be completed by 3rd Qtr 2013.
- By 1st Qtr 2014 replace 230 kV Redmond bank T01626 (3-phase), and put the spare transformer T01670 back on standby.
- By 1st Qtr 2014 replace 500 kV Pearl T01784 (single phase).
- By 1st Qtr 2015 replace Yaak 115 kV transformer T00502

Capital (Substantial Betterments- SB) & Expense

- By 2nd QTR 2013 SB - Complete bushing upgrades on 2 additional transformers to eliminate capacity limits (bottleneck)
- By 4th QTR 2014 SB - Complete all Type "U" bushing replacements.
 - The bushings are capital as they provide substantial betterment. Labor is expense for bushing upgrades and Type U bushing replacements.
- Expense - Complete 10-15 load tap changer services (contracted work) annually. (Number based off historic trends)

Executive Summary

What equipment is covered?

Strategic environment & drivers

Strategies

Process improvements

Equipment Strategies

- Power transformers and reactors
- **Switchgear**
- Shunt capacitors
- Instrument transformers and surge arresters
- Station auxiliary
- Substation bus & structures



What will it cost?

Program Accomplishments FY10 & FY11

Switchgear: Asset Criticality

- Power Circuit Breakers (PCB) provide a means to clear system faults, and protect substation equipment such as Power Transformers from damaging system disturbances (faults, lightning).
- Circuit Switchers (CS) are primarily used to switch reactive equipment (Capacitors and Reactors) in and out of service. Circuit Switchers are also used on a limited basis to clear faults.
- Disconnect Switches (DS) allow isolation of equipment from energized parts of the system and facilitate the maintenance of high voltage equipment in substations and on transmission lines.
- Both Substation and Transmission Line priority ranking criteria will establish the criticality of all switchgear and will be used to determine the magnitude and consequence of an outage for purposes of assessing risk.

Switchgear: Performance Objectives

Performance Objective - Maintenance, All Switchgear: Manage workload and resources to avoid regularly scheduled preventative maintenance to exceed 25% past target due date.

– **Measure(s):**

- Number of switchgear that are more than 25% past their scheduled service dates unless there are acceptable mitigating factors (i.e. planned replacement within 2 years or less).

– **End-Stage Target(s):**

- 100% of all WECC and OB-19 Significant Equipment switchgear maintenance shall be completed within the prescribed timeline – not to exceed 125% of the total maintenance interval.
 - The only exception is if there is a deferral of the maintenance service approved by a subject matter expert in Substation Maintenance and High Voltage Engineering.

Performance Objective - Replacements: Prioritize the replacement of switchgear based on system criticality and performance. Those that ranked at high system risk (“high system impact” and “poor” condition”) and cannot be maintained and refurbished to a reliable operating condition will be scheduled for replacement.

– **Measure(s):**

- Number or percent of replacement project designs and/or installations completed to meet the start of year (SOY) projection for the asset group. Allow for adjustments based on resource (\$, labor, materials) availability.

– **End-Stage Target(s):**

- Complete all “emergency” replacements within the timeframe prescribed by Substation Maintenance and High Voltage Engineering (TESM) and System Operations (TOP).
- In any fiscal year 85% of designs will be completed for all new start switchgear replacements.
- In any fiscal year 80% of the prior years’ planned switchgear replacements will have been installed and energized.

Switchgear: Performance Objectives (2)

Performance Objective - Fault Duty Upgrades: - Avoid generation curtailment, bus sectionalizing (possible N-2 contingency), and increased safety risk due to inadequate nameplate ratings for fault duty on in service switchgear.

Applicable standards:

1. National Electrical Safety Code Section 17 , NERC TOP-004-2, NERC FAC-010. Comply with NESC Section 17 paragraph 171: . . . "Devices that are intended to interrupt fault current shall be capable of safely interrupting the maximum short-circuit current they are intended to interrupt, and for the circumstances under which they are designed to operate. The interrupting capacity should be reviewed prior to each significant system change."
2. NERC TOP-004-2, B. Requirements, R1. "Each Transmission Operator shall operate within the Interconnection Reliability Operating Limits (IROLs) and System Operating Limits (SOLs)."

– Measure(s):

- Complete system fault current studies, breaker analysis, and Project Requirements Diagrams (PRD) to identify required fault duty switchgear upgrades and replacements.
- Complete design and construction of fault duty switchgear replacements.

– End-Stage Target(s):

- By the end of 1st QTR, each year, complete initial system wide fault study's and switchgear analysis (TESM) for the subsequent 2 year capital planning cycle.
- By March 15th (beginning 3rd QTR) – Switchgear Replacement PRD's are issued (TOP) for the subsequent 2 year capital planning cycle.
- By the end of 2nd QTR business cases and resource schedules are completed for the subsequent 2 year capital planning cycle.
- Complete 100% of replacements/upgrades of underrated switchgear within 2 years prior to system fault current exceeding switchgear ratings.

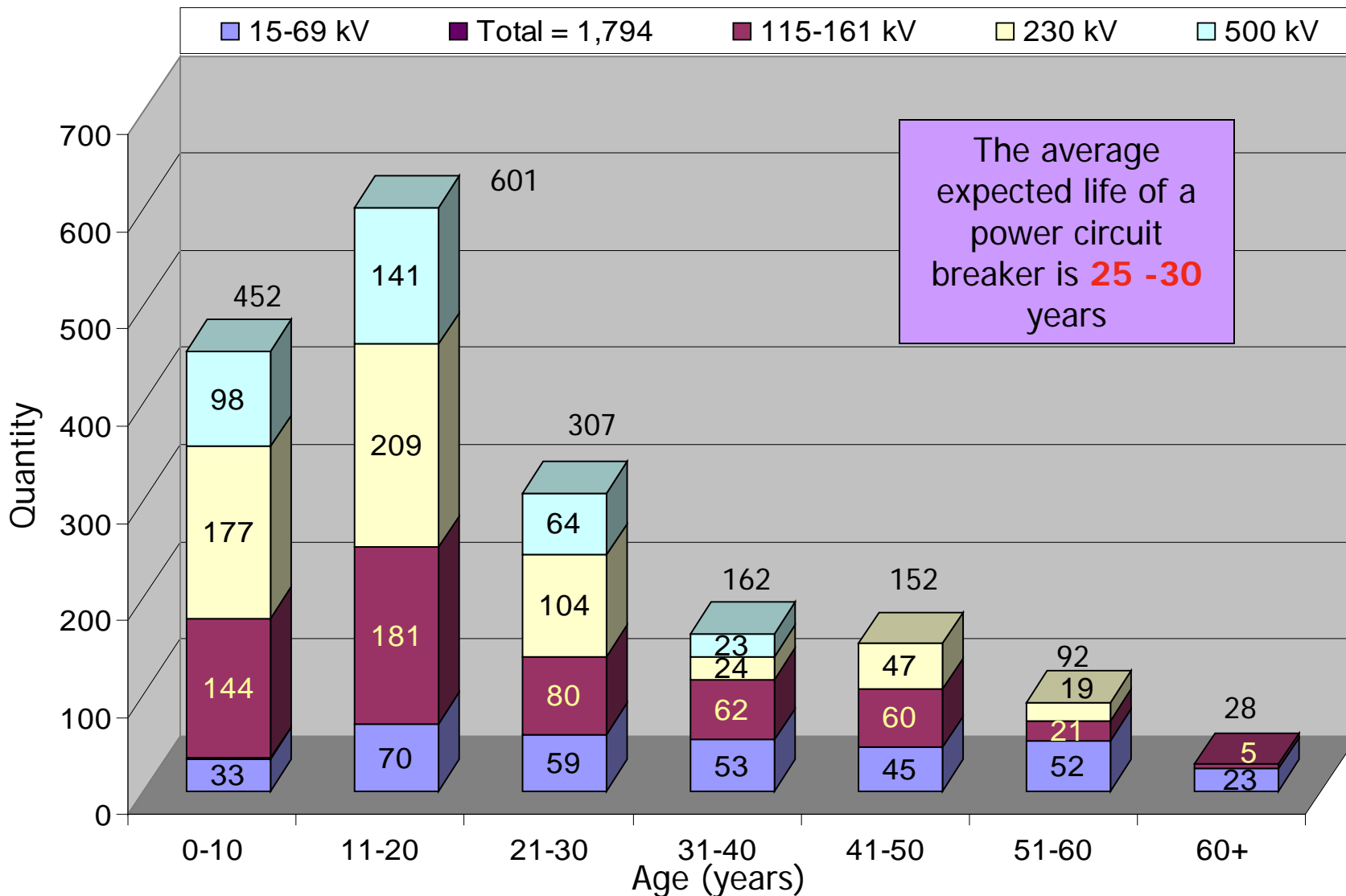
Switchgear: Current State of the Assets

Circuit Breakers, Circuit Switchers, and Disconnect Switches

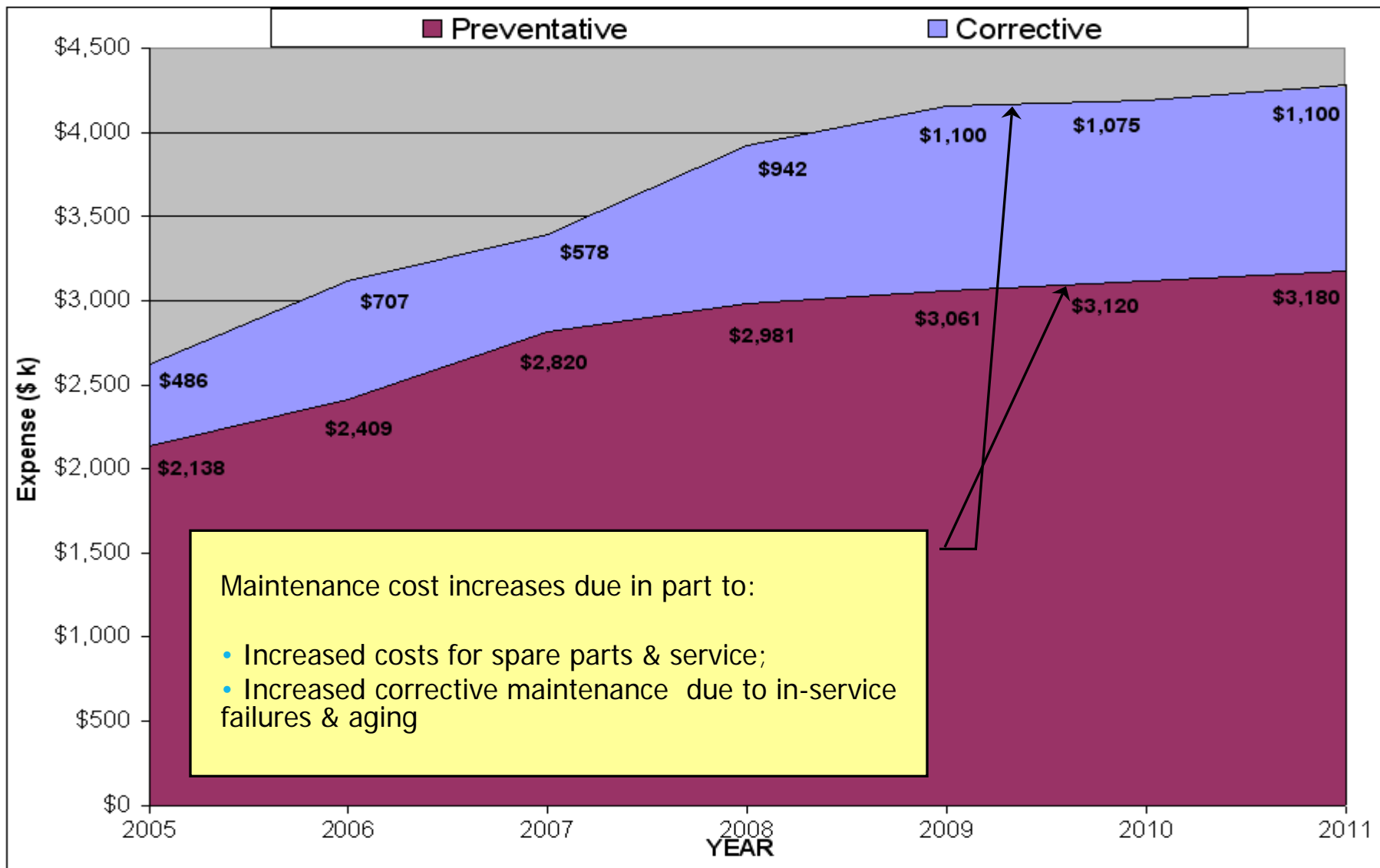
Key issues with the current state - General Problem Areas:

- The availability and cost of spare parts is the most significant factor in keeping all switchgear operating reliably. The decline in vendor support, for both parts and refurbishment service, will drive an increase in replacements whether planned or unplanned.
- The majority of replacements are based on the availability of spare parts and cost of those parts compared to the remaining life, frequency and cost of repairs, and the frequency of failures.
- Many existing breakers and switchers are maintenance intensive due to their complexity – mechanical (hydraulic, spring, combination), insulation systems (oil, air, SF6, vacuum)
- Life extensions may be performed but do not always deliver the expected additional life. Parts used in life extensions, rebuilds/refurbishments are often aged, salvaged, or inferior quality to the original part and may last only a fraction of the original parts' lifespan.

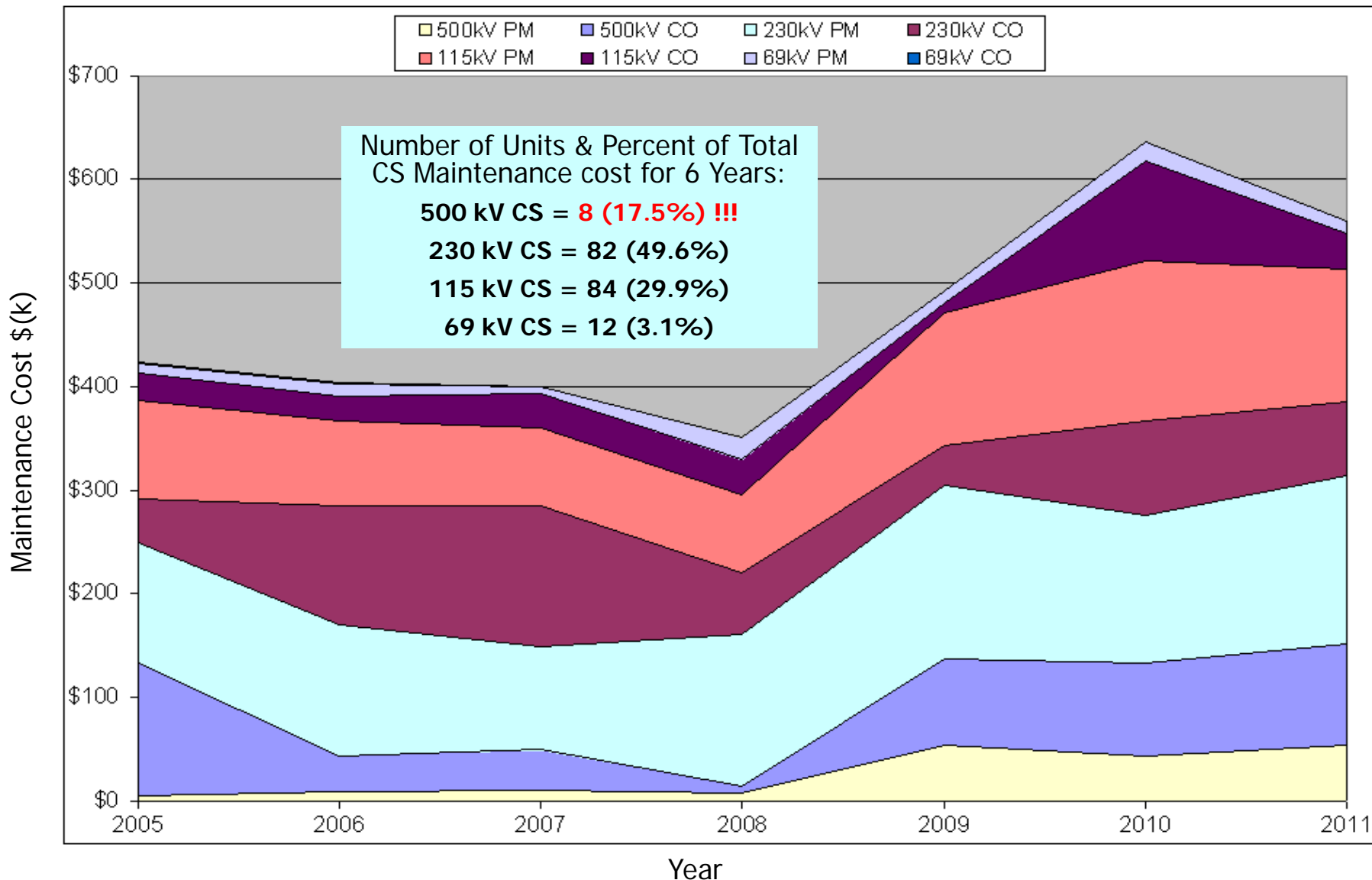
Switchgear: Current State of the Assets – (Breaker Age Demographics)



Maintenance Costs – All Circuit Breakers



Maintenance Costs – All Circuit Switchers



Switchgear: Failure modes

Power Circuit Breakers and Circuit Switchers:

- Mechanical Failures - Operating mechanism (Most Common failure mode) - Moderate to high repair cost, may damage the breaker or switcher beyond repair.
- Insulation Failures – Failure of the insulating medium, SF6 Gas, Oil, Air, or vacuum leads to internal faults (least common failure mode) – Moderate to high repair cost, may have significant system impact due to longer repair time, can damage the breaker or switcher beyond repair. Has NEPA Implications - SF6 Green house gas emission regulations or oil contamination of soil or water.
- Control failures – (Most common after Mechanical Failures) - Tend to be least cost to repair but can have significant system impacts during failure.

Disconnect Switches:

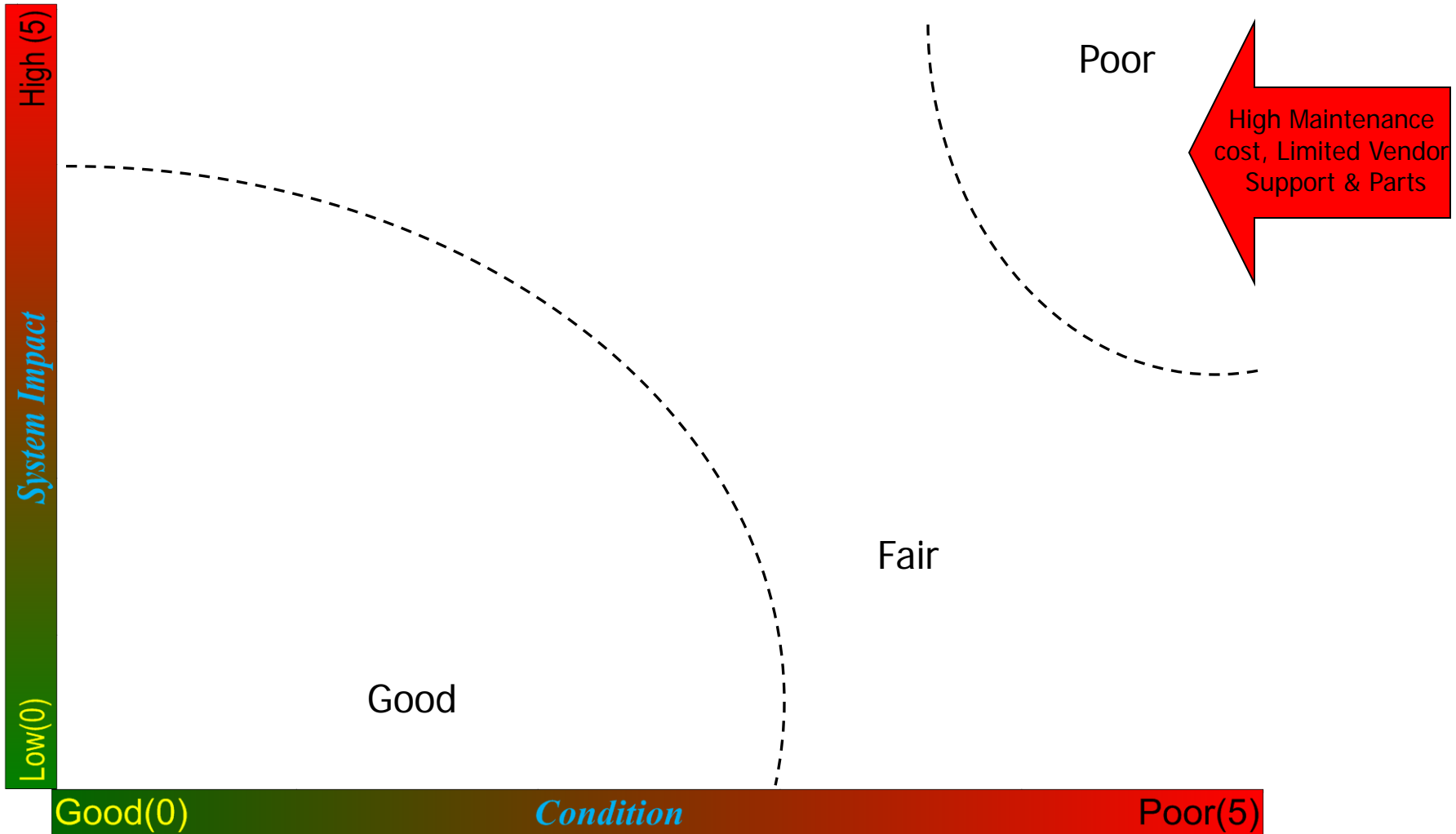
- Mechanical Failures – The moving parts of the switch itself or the operators (manual or motor operated) wear out over time inhibiting the safe opening and closing of the switches.

Switchgear : Failure Modes (2)

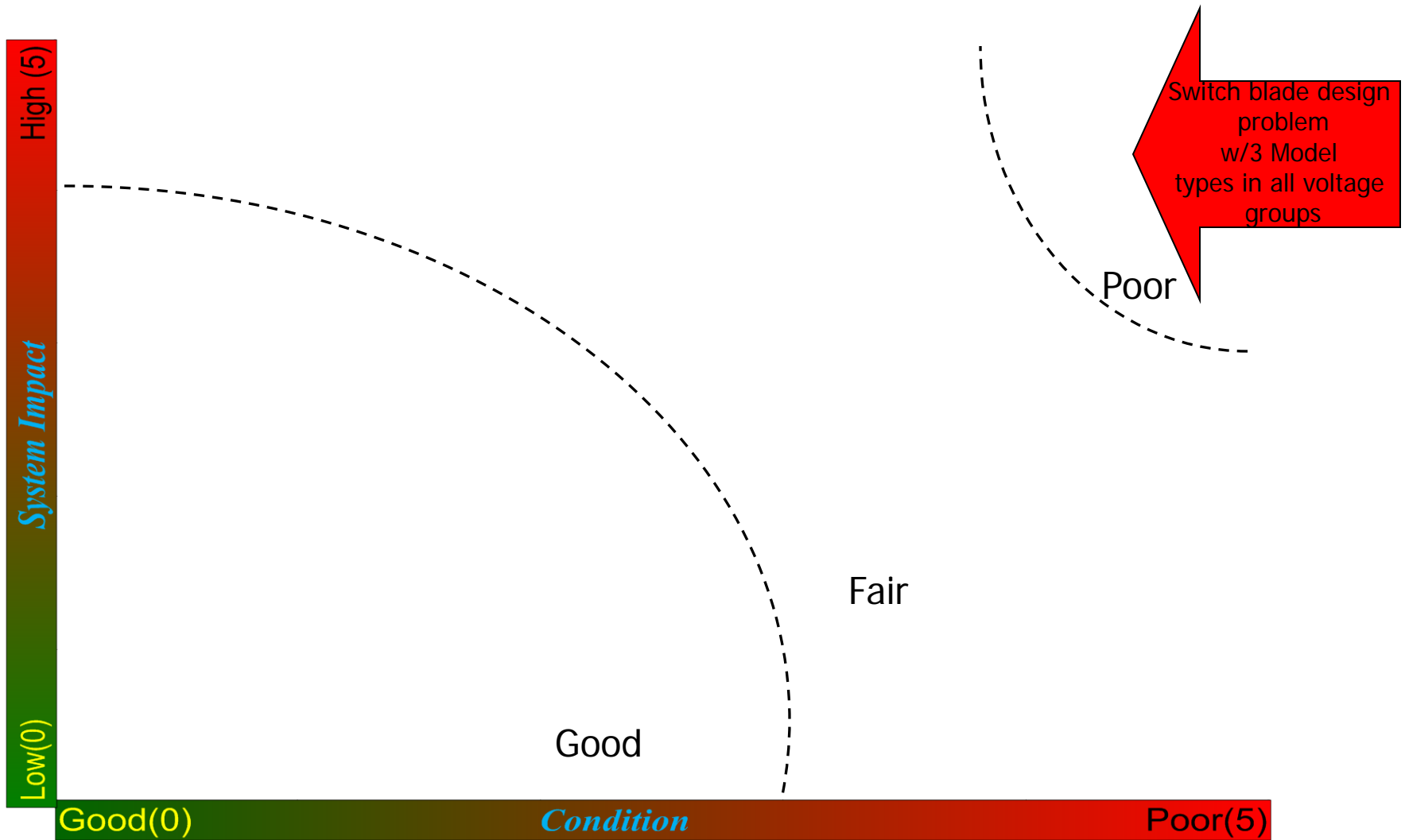
Disconnect Switches:

- Insulator failures - Fatigue on Low voltage fused disconnects - Safety Hazard: Insulator Failures occur during open/close manual operation. Where replacement insulators cannot be fitted to the old switch or other excessive wear is present the switch is replaced.
- Hydraulic operating mechanisms - Failures on certain models of 500 kV and 230 kV motor operated disconnects are increasing due to component end of life and inability to obtain spare parts to repair the hydraulic mechanisms.
- Mechanical Failures – The moving parts of a disconnect switch itself or the operators (manual or motor operated) wear out over time inhibiting the safe opening and closing of the switches. Poorly functioning switches increase arcing during opening that may put operators at risk, introduce “noise” into the system, and prematurely wear out the contacts.
 - Disconnects: Increased failure rates of insulators on low voltage 15 kV class fused disconnect switches and inability to retrofit the older switches with new insulators.
- Mechanical Design Flaws – Safety Hazard: The RV 500, MK-40, and TA-4 Model switches were recently found to have a design defect that does not provide positive mechanical restraint of the switch blade in the open position and can result in inadvertent closing of the blade.
 - Disconnects: The recent identification of approximately 110 switches with models in the 115, 230 & 500 kV voltage classes with safety restraint problems. Modifications are not possible on these models without switch redesigns and the vendors are no longer in business.

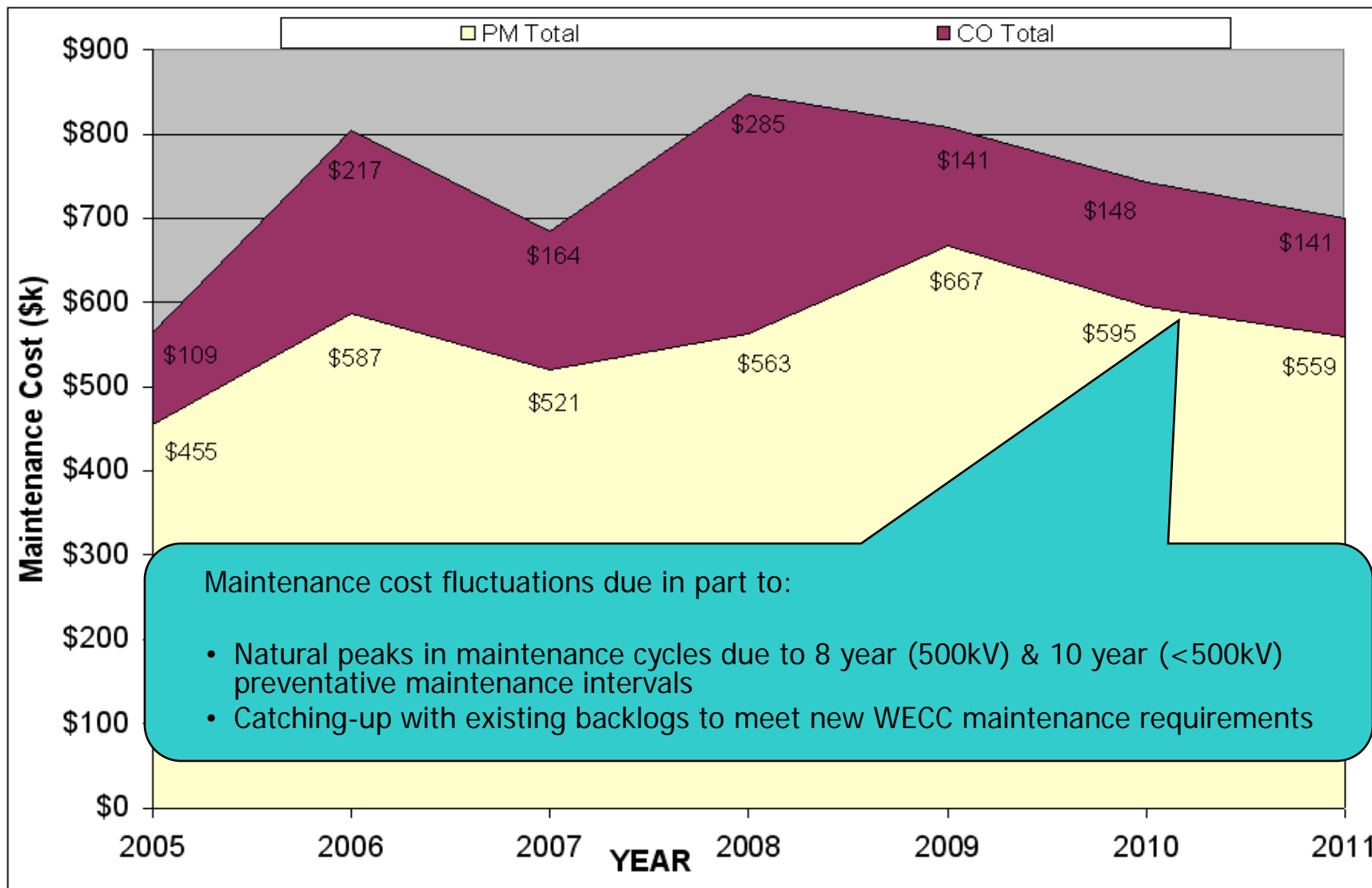
Switchgear: Assessing Risk for Circuit Breakers (PCB) & Circuit Switchers (CS)



Disconnect Switches: Assessing Risk



Maintenance Costs – All Disconnect Switches



Switchgear Strategy

1. Maintenance (preventative & corrective) including stocking or securing quick access to stocked spare parts and vendor supplied parts.
2. Spares - Maintaining emergency spares (EMS) – strategy is to have breakers, circuit switchers and disconnects that can cover all voltage classes. For switchgear, “Strategic Sourcing” will be used to secure Master Agreements and Compliance Contracts to optimize cost and delivery time.
 - Emergency Stock (EMS) - goal is to have at least one spare that can be applied to each of the following voltage classes, 15, 34.5, 69, 115, 138, 161, 230, 287, 345 and 500kV for all switchgear types. In addition - for breakers, there will be at least two spares at 115, 230, & 500 kV. In some cases a higher voltage rating may be used to cover for a lower one (i.e.: a 345-kV switch for 287 kV). Keeping the stocking numbers down and using higher voltage ratings in a lower voltage position help maximize the benefit/cost ratio.
 - Switchgear EMS levels are based on much shorter lead time compared to transformers. The ability to obtain a replacement varies from two weeks to six months
 - Emergency O&M agreements allow for purchase of equipment from partner utilities but will not be relied upon as a primary source of spare equipment.
3. Data gathering (inspect, test, monitor) as applicable to develop failure prediction and replacement algorithms.
 - Monitor/Record/Analyze Data - Parameters to be monitored and recorded:
 - System risk data (external to CASCADE) SCADA, PI, OARS, SER, DIR, TOA, DTA, WPSS
 - I^2t and cumulative fault current
 - Relay coil signatures and contact wear
 - Gas density/purity
 - Duty type, number of operations, etc.
 - Insulation system condition (SF6 moisture/purity, SF6/Oil leaks)
 - Bushing power factor, bushing condition
 - Mechanical operating system condition (hydraulics, springs, compressors, etc.)
 - Electronic control systems
 - Relay signatures and current [amps] data could be collected with the replacement/upgrade of older relays with digital “smart relays” where criticality and equipment value make it cost effective. Smart relays can provide similar data to SCADA, PI, SER but integrated with specific breaker and relay operating characteristics.

Switchgear: Strategy – Condition driven replacements

Modern circuit breakers and circuit switchers, mostly SF6, mixed gas, air or vacuum devices, have an average expected life span of 25 - 30 years.

Due to the large number of individual parts circuit breakers and circuit switchers are highly repairable. Destructive failure is largely avoidable on these devices since most units are replaced when they can no longer be repaired. Circuit breakers and circuit switchers are typically replaced when spare parts are no longer available or the optimum life cycle cost has been exceeded.

– Strategy Focus:

- Breakers: Certain models of oil circuit breakers are obsolete due to a lack of spare parts. Some life extensions/partial rebuilds are not providing the expected 15 years of extended, reliable service. Certain models are no longer repairable - reliability is falling in spite of service/maintenance.
- Circuit Switcher: Manufacturer support and spare parts for 230 kV and 500 kV S&C Mark IV & Mark V is diminishing - combined with a steady increase in the replacement rate of interrupters and operating mechanisms, and a decline in the life/performance of the replacement interrupters. Replacement parts and maintenance costs have exceeded the material replacement cost, over a 6 - 8 year period for most 500 kV units.

Switchgear: Strategy – Condition driven replacements (2)

Disconnect switches have an average lifespan of 35-45 years which is very dependent on the type of usage and the ability to repair and replace components.

Similar to circuit breakers and circuit switchers disconnects have a large number of individual parts, and are highly repairable. Violent failure is very rare due to the lack of a pressurized insulation medium. Units are replaced when they can no longer be repaired or repair cost and frequency exceed optimum life-cycle. Poorly functioning switches increase arcing during opening that may put operators at risk, introduce “noise” into the system, and prematurely wear out the contacts.

– Strategy Focus:

- Mechanical Failures - The recent identification of approximately 110 switches with models in the 115, 230 & 500 kV voltage classes with safety restraint problems and no spare parts - modifications are not possible on these models without switch redesigns and the vendors are no longer in business.
- Insulator Failures - Fatigue on Low voltage fused disconnects - Safety Hazard: Insulator Failures occur during open/close during manual operation. Where replacement insulators cannot be fitted to the old switch or other excessive wear is present the switch is replaced.
- Hydraulic Operating Mechanisms - Failures on certain models of 500 kV and 230 kV motor operated disconnects are increasing due to component end of life and inability to obtain spare parts to repair the hydraulic mechanisms – 50 total.

When making replacements, switchgear will be of proven technology from industry leaders in reliability. Application of equipment will be made to meet current system operating demands and projected load and generation growth.

Postponement of planned switchgear replacements shall be coordinated and approved by both the Substation AC Sustain Program Manager and the Substation Maintenance engineer responsible for prioritizing condition based switchgear replacements.

Switchgear: Strategy - Fault Duty driven replacements

- Fault current system studies are conducted bi-annually for the entire transmission system.
- Individual, localized, studies are conducted for every new proposed generation project or generation expansion.
- Fault studies are also conducted for any new line additions, line reconfigurations, transformer additions/removals that were not included in the bi-annual studies.
- Fault current studies and subsequent switchgear fault duty analysis shall be geared toward a two year design and construction upgrade window. This will provide adequate time for design, material procurement, and labor resource scheduling.

Implementation Milestones

Fault duty switchgear - Avoid standards violations.

- **Measure(s):**
 - Any existing safety restrictions (limiting work around underrated equipment) and operating restrictions/temporary operating bulletins are eliminated.
- **End-Stage Target(s):**
 - 4th QTR 2012 100% of prior years' (2010 & 11) fault duty circuit breakers and circuit switcher upgrades/replacements have been completed.

Emergency Spares - Ensure that equipment and procedures are in place to facilitate service restoration for emergency replacements/failures.

- **Measure(s):**
 - EMS PCB's, CS's, and DS's are issued on an "as-needed" basis after review by SME's for proper rating application. Stock is cycled and usage triggers a re-order to pre-defined stocking levels. EMS PCB's, CS's, and DS's are checked for condition and readiness on a monthly basis to minimize restoration time. Reporting on existing and re-ordered EMS equipment is available from TESH and Substation Design.
- **End-Stage Target(s):**
 - In 2011 95% of all emergency replacements are achieved with "on hand" EMS stock for complete units (2ea emergency replacement in FY2011: Troy L-953, Marion 4355 – both replaced using "on-hand" EMS equipment). This is done to ensure cycling of the EMS stock equipment.
 - By 2nd QTR 2012 80% of all preventative maintenance repairs are achieved with spare parts on hand. Parts consisting of major components not readily available (interrupters, contactors, control relays, arcing contacts, motor operators, "O" rings, etc.)

Executive Summary

What equipment is covered?

Strategic environment & drivers

Strategies

Process improvements

Equipment Strategies

- Power transformers and reactors
- Switchgear
- **Shunt capacitors**
- Instrument transformers and surge arresters
- Station auxiliary
- Substation bus & structures



What will it cost?

Program Accomplishments FY10 & FY11

Shunt Capacitors: Asset Criticality

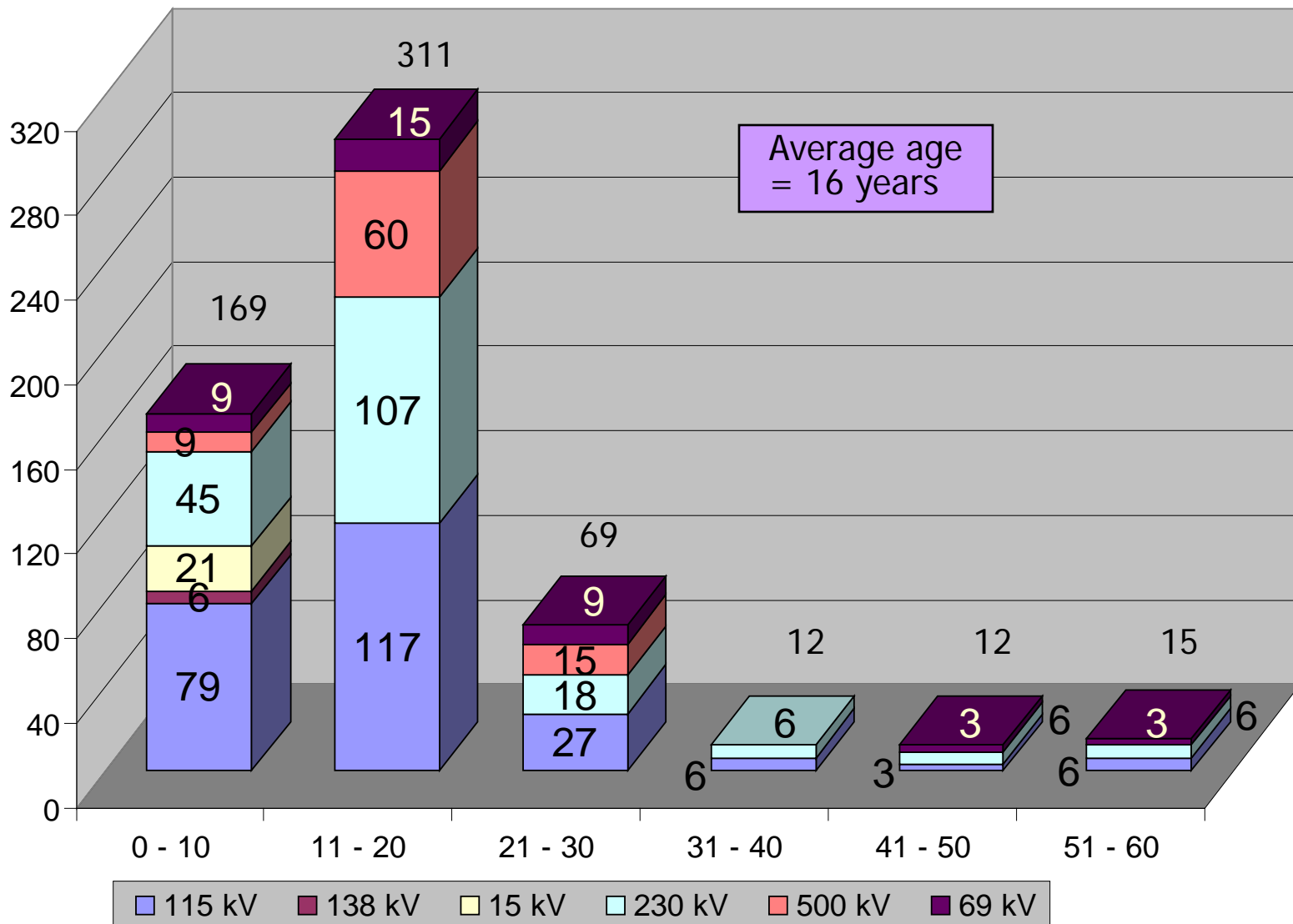
- Capacitors provide additional transmission capacity by boosting voltage and decreasing reactive line losses thereby increasing power transfer between lines and stations on both BPA's system and interconnected utilities and generators.
- Small air core current limiting reactors are part of this asset group as they are used in conjunction with multiple capacitor groups on the same bus to limit high currents that can damage capacitors while switching. When more than one capacitor group is connected to a bus and either one can be switched while the other is in service it is called "back-to-back" switching.
- The criticality of shunt capacitors is determined by Transmissions priority ranking criteria combined with system contingencies, and RAS – these include extreme weather conditions that increase system loading.
- As a result of aggressive environmental mitigation all of BPA's shunt capacitors are PCB free. Compared to other AC asset groups the average age of BPA's shunt capacitors is 16 years which is relatively moderate in age due to the PCB replacement program completed in 2004.

Shunt Capacitors: Performance Objectives

For Fused & Fuseless Capacitors and associated current limiting reactors (CLR's)

- **Performance Objective:** Avoid reductions in ATC/OTC for loss of shunt capacitor groups or sections. Critical during heavy load conditions. Critical links: Availability of capacitors is contingent on both the relays and switchgear (breakers & circuit switchers) used to protect and control the capacitors.
 - Measure(s):
 - Reductions in ATC/OTC
 - Load shedding to avoid system collapse or system instability
 - Reliability of breakers or circuit switchers used to switch capacitors in and out of service
 - Reliability of control & protection relays for shunt capacitor (Performance Targets in SPC Asset Strategy)
 - Spare capacitors, fuses and associated hardware are stocked for all capacitor ratings installed on the system
 - End-Stage Target(s):
 - By 3rd QTR 2012 Criteria is developed to correlate shunt capacitor availability to ATC/OTC
 - Performance targets are developed for switchgear and relays in their respective Asset strategies
- **Performance Objective:** Avoid operating restrictions of shunt capacitor groups for loss of a current limiting reactor. Current limiting reactors reduce the exchange of high current between capacitor groups that can damage capacitors during switching.
 - Measure(s):
 - All stations with multiple capacitor groups on the same bus shall be capable of back-to-back switching.
 - End-Stage Target(s):
 - By 4th QTR 2015 install CLR's at three remaining sites so that existing operating restrictions for back-to-back capacitor switching can be eliminated.

Shunt Capacitors: Age Demographics



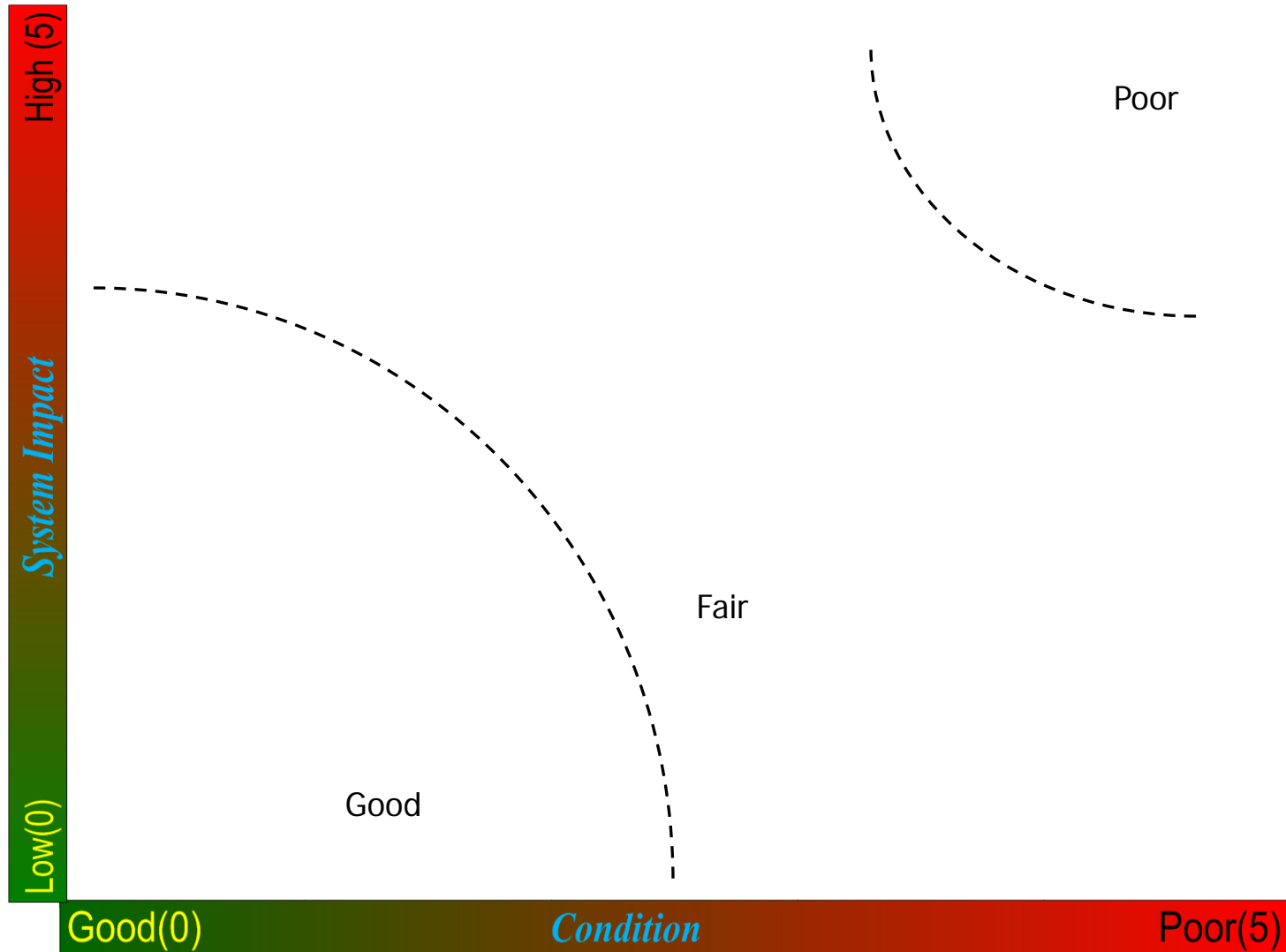
Shunt Capacitors: Failures Modes

Capacitors are made up of many individual units often referred to as “cans” that are connected together to form “groups” and “sections” for operating purposes. There are three main types of capacitors that are defined by the way individual cans are protected: externally fused, internally fused, and fuseless. Capacitors are connected in various combinations of series and parallel strings made up of lower voltage (ex. 22 kV) units to make a complete group that operates at the various system voltages (69kV - 500kV)

In general entire capacitor groups or sections are replaced infrequently for condition driven factors since individual cans are replaced as needed. Some exceptions are an excessive quantity of capacitor can failures that may be attributable to a poor design or poor manufacturing quality.

- Capacitors fail when their internal wrappings are damaged due to high electrical stresses (voltage or current) or when moisture invades the sealed units also leading to electrical stress failures. Capacitor failures are primarily a failure of the internal insulation of the individual cans. The internal insulation frequently includes some type of insulating material such as paper and/or Mylar which are impregnated with an oil such as mineral oil.
- Capacitor condition is based on individual capacitor “can” (single capacitor unit) failure rates, which is largely based on electrical stresses, age and, and moisture ingress that leads to the deterioration of the capacitors’ internal insulation.
- Fuse failures for fused shunt capacitors, premature degradation due to weather/moisture.
- Switching frequency (in and out) and exposure to transients that degrade insulation.
- For very old capacitor designs the existing racks and foundations may no longer meet the basic structural and/or seismic design requirements particularly if the newer replacement cans are physically larger, heavier, or the dimensions of the new cans won’t fit the old rack.

Shunt Capacitors: Assessing risks



Shunt Capacitors: Strategy

The shunt capacitor strategy for both fused and fuseless types is focused on four key areas:

- Performance monitoring and data analysis
- Maintenance and operations approaches
- Equipment standardization
- Maintaining the proper level of spare equipment and parts

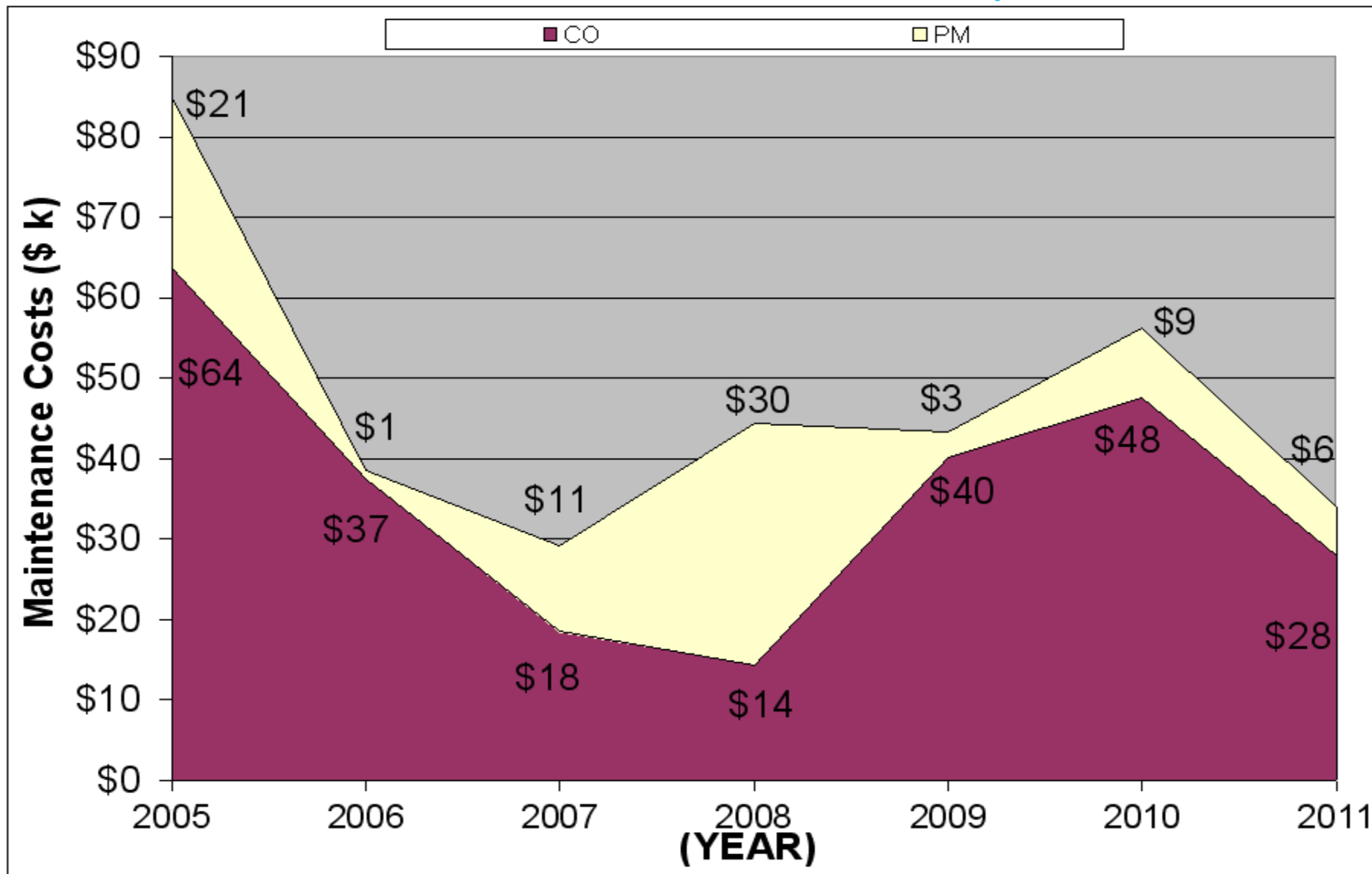
Monitor/Record/Analyze Data

- Parameters to be monitored and recorded:
 - Voltage measurement/monitoring for capacitor groups & sections
 - Bushing & can condition (contamination, bulging, discoloration, moisture ingress)
 - Condition of associated PT's and control relays
- Maintenance data to be recorded (include frequency, maintenance hours, cost)
 - String capacitance (fuseless banks)
 - Capacitor can oil leaks
- Analyze
 - Capacitor can & fuse failure rates

Optimal Replacement Window

- Capacitors have an average expected life span of 25-30 years.
- Capacitor "Groups" are highly repairable since individual cans and fuses can be replaced up to a certain point. If can or fuse failures become excessive then a complete replacement may be needed.
- Up to this point obtaining replacement cans and fuses has not been an issue since most standard sizes and ratings are still available from either the OEM or substitutions can frequently be made.
- If the existing capacitor rack and foundations design cannot accommodate changes in capacitor can or fuse design and still meet seismic requirement then a complete replacement will be required.
- When making replacements, capacitors will be proven technology from industry leaders in reliability. Application of equipment will be made to meet system operating demands. Installation will include testing and verification of operation.

Maintenance Costs – All Shunt Capacitors



Shunt Capacitor: Purchasing and Spare Equipment Policies

- For emergencies BPA maintains two relatively small portable capacitor groups. One group is rated for 69 or 115 kV operation and the other is rated for 230 kV operation. Both portable units have dedicated circuit switchers, protection and control relaying, and portable battery sets to operate the relays and circuit switcher.
- Portable Capacitors - The current strategy is based on practical limits associated with size and historic need. Existing portable groups are sized for 69kV and 115kV application with relatively small ratings. However, the current strategy should be evaluated and either reaffirmed or updated as needed.
- Due to the relatively small number of new capacitors installed on the system today and the current practice of replacing individual cans rather than entire capacitor groups we currently do not have a master contract and there does not appear to be significant benefit in pursuing strategic sourcing due to the low volume.
- Maintain adequate levels of inventory (capacitor cans, fuses and associated hardware) for all sizes in service today. Inventory is to be located in the field and centrally for rapid response.
- Maintain adequate levels of supporting equipment such as switchgear, instrument transformers, and relays that provide control and protection. The asset strategy's for the supporting equipment reflects the performance requirements for the shunt capacitor assets.

Shunt Capacitor: Implementation Milestones

Sparing Strategy

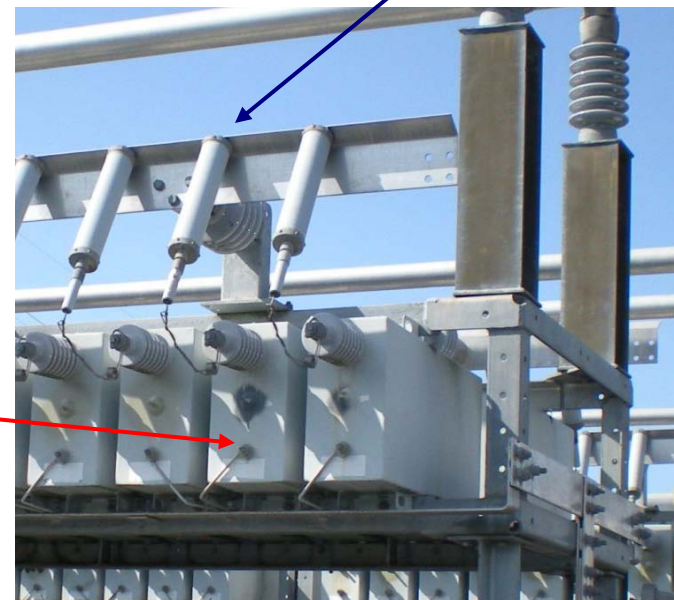
- Spare inventory for all capacitor sizes and ratings currently in service is evaluated annually by Substation Maintenance and High Voltage Engineering subject matter expert.
- Annually: Confirm 24 hour readiness of the two mobile/spare capacitor groups.

Capital

- By 4th Qtr 2013 replace the 115 kV Tillamook capacitor bank
Entire bank including concrete footings, racks, cans, CLR's, etc.
- By 4th QTR 2014 replace the 115 kV Bell capacitors
(cans only)
- By 4th QTR 2014 replace the 500 kV Echo Lake capacitors
(cans only)

Individual capacitors
"cans"

Fuses



Executive Summary

What equipment is covered?

Strategic environment & drivers

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Process improvements

Equipment Strategies

- Power transformers and reactors
- Switchgear
- Shunt capacitors
- **Instrument transformers and surge arresters**
- Station auxiliary
- Substation bus & structures



What will it cost?

Program Accomplishments FY10 & FY11

Instrument Transformers: Asset Criticality

Instrument Transformers (IT) - System Indication and Data Measurement

- Instrument transformers provide the raw current and voltage data from the power system for protection and control relaying, revenue meter data, AGC, generation and stability control, and condition monitoring.

Instrument Transformers - Criticality:

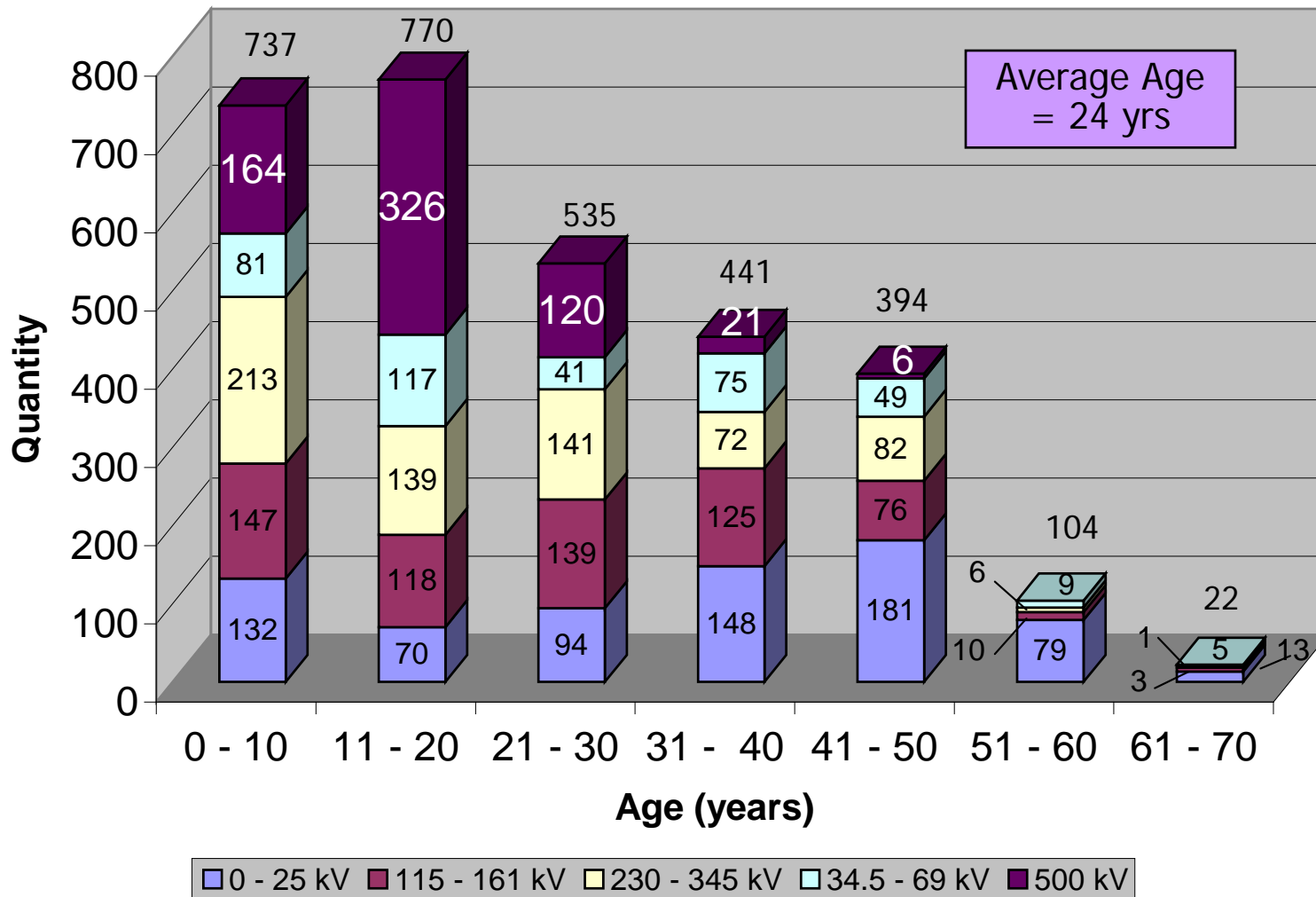
- The combination of Substation and Transmission Line priority ranking criteria establishes the criticality of all instrument transformers.
- The availability of spare or stock units, transformer condition and loading, critical contingencies, and revenue data sensitivity will be used to determine the magnitude and consequence of an outage for purposes of assessing risk.
- Key data:
 - Instrument transformer condition is based on age, insulation performance (bushings, windings, coupling capacitors), and voltage or current accuracy.
 - Function – Provide the raw system data/measurements for protective relaying & control, metering, AGC, RAS, SCADA, synchronization, WAM, hot line indication, etc.
 - Potential for PCB contaminated insulation oil

Instrument Transformer Performance Objectives

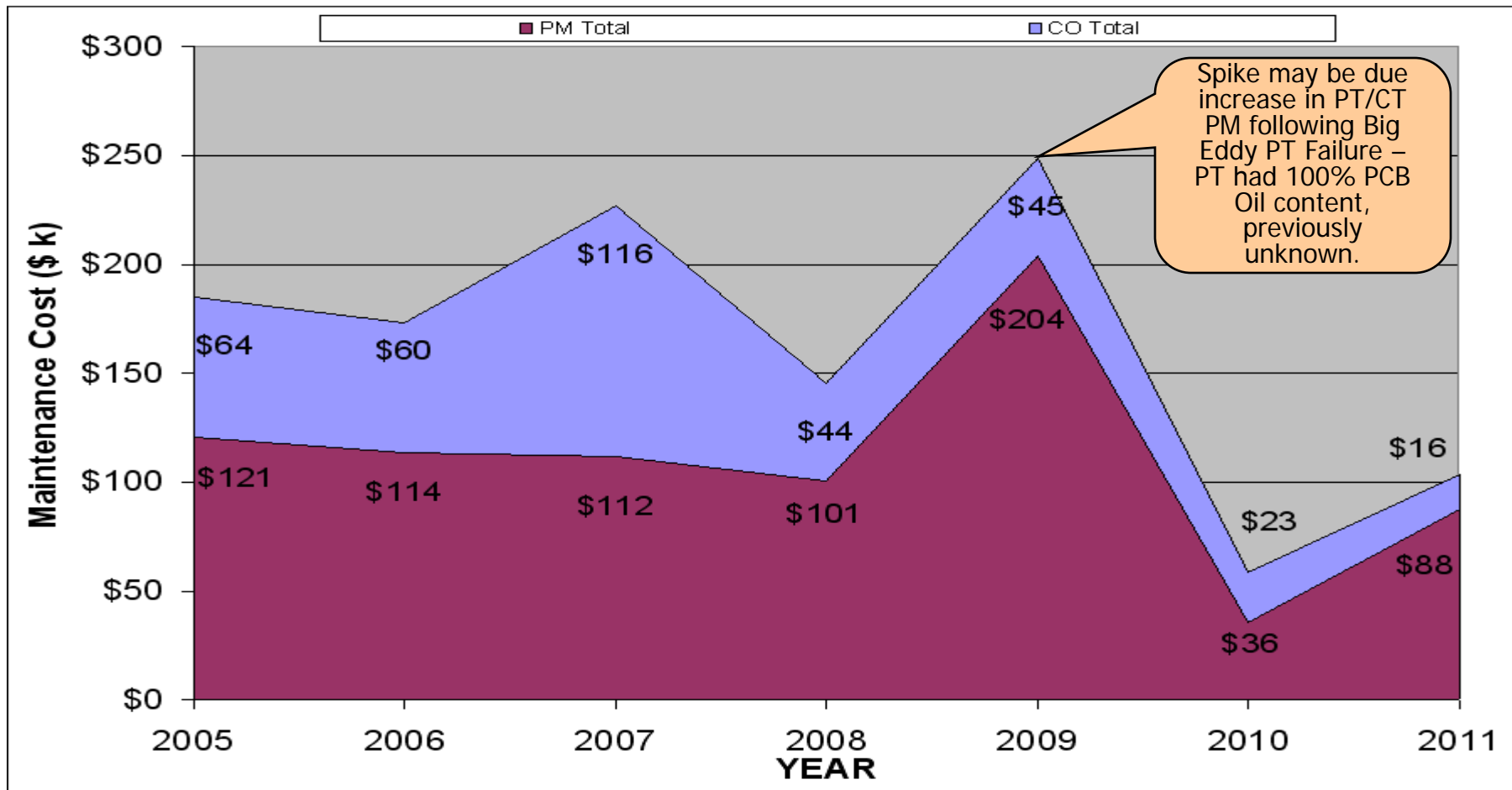
Instrument Transformers (IT): PT/VT/CVT/ - potential & voltage transformers, CT - current transformers

- **IT Performance Objective:** Instrument transformers are themselves monitoring equipment that provide the raw data used by relays, meters, AGC, etc. to control and protect the system and for revenue meter data. Maximize availability and plan for replacements to avoid data accuracy problems associated with failing insulation or drifting of capacitor characteristics. IT's have very few if any maintainable/replaceable parts with the exception of oil gaskets.
 - **Measure(s):**
 - PT/VT/CVT - Secondary voltage monitoring & CT – secondary current accuracy
 - Winding tests & Capacitance tests (drifting – only for CVT's)
 - Power factor tests (insulation failure) – Oil Filled > 69 kV
 - Oil leak for non dry type transformers (>46 kV), PCB contamination is an issue with older (1979 and older) vintages
 - Failure trending – all IT types
 - **Strategy:**
 - Due to limited main bus outages – target all three (same age and model) phases for replacement
 - **End-Stage Target(s):**
 - By 4th QTR 2012 criteria will be developed based on failure trending to predict optimum replacement time
 - Replace remaining 1,100 IT's containing PCBs \geq 50 ppm by 2025. These IT's are regulated by the Toxic Substance Control Act - shared goal with Environment Fish & Wildlife (EF&W) – link to asset strategy for EF&W.

Instrument Transformer: Age Demographics



Maintenance Costs – All Instrument Transformers



Maintenance cost fluctuations due in part to:

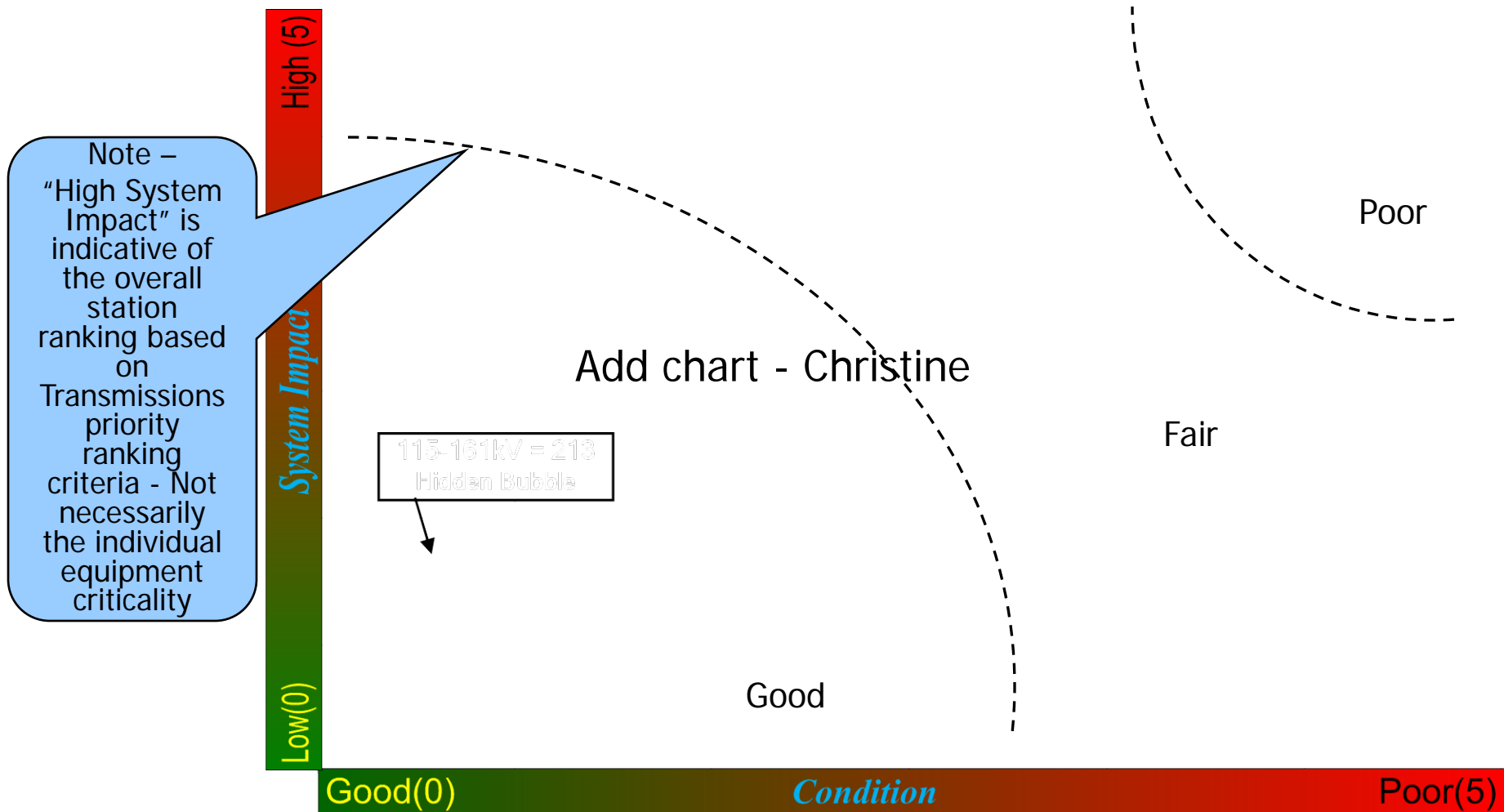
- Natural peaks in maintenance due to 7 – 10 year preventative maintenance intervals;
- Catching-up with old backlogs to meet new WECC maintenance req's.;
- Some reduction in maintenance due to FY 2009/2010/2011 increases in capital replacements due to environmental drivers and in service failures including replacement of sister units;

Instrument Transformer: Failure Modes

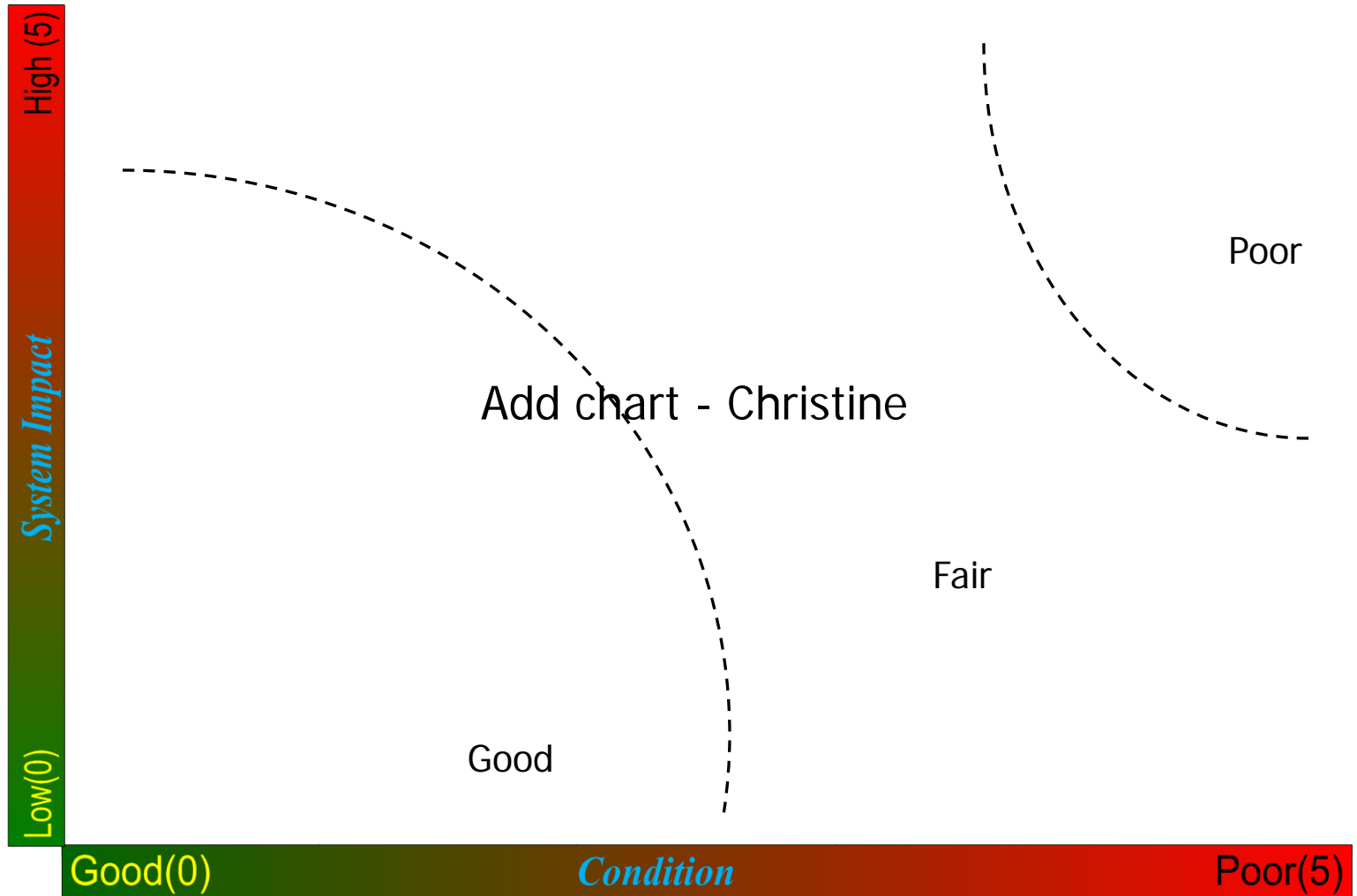
Instrument transformer (IT's) consist of two major groupings listed below. Both types are used and needed for control and protection, revenue metering, and other forms of data acquisition for RAS, SCADA indication, PMU, Communications, etc..

1. Voltage Transformers – includes wirewound potential transformers, and CVT / CCVT – capacitively coupled voltage transformers
2. Current Transformers – include wire wound transformers, and less common are Hall effect devices.
 - IT's fail primarily due to insulation or bushing failures -similar to both power transformer/reactor and capacitor failures.
 - IT's tend to have permanently sealed housings and are generally not repairable with the exception of some high voltage units that are partially oil filled and can have gaskets replaced.
 - Most lower voltage IT's typically below 46 kV are dry type and have no appreciable oil inside them.

Instrument Transformer: Voltage and Potential transformers - Assessing Risks



Instrument Transformer: Current transformers - Assessing Risks



Instrument Transformer: Strategy

The instrument transformer strategy for both voltage and current transformers is focused on four key areas:

- Performance monitoring and data analysis
- Maintenance and operations approaches
- Equipment standardization
- Maintaining the proper level of spare equipment and parts

Monitor/Record/Analyze Data

- Parameters to be monitored and recorded:
 - Voltage and current measurement/monitoring on the secondary windings
 - Bushing and insulation condition (oil leaks, external arcing, moisture ingress)
- Maintenance data to be recorded
 - Secondary winding voltage or current measurement
 - Capacitance for CVT/CCVT
 - Density monitor calibration for SF6 gas filled IT's
- Analyze
 - Failure and leak rates by model, voltage, and design type

Optimal Replacement Window

- Instrument transformers have an average expected life span of 25-35 years.
- Failed units are typically replaced due to limited ability to repair.
- Standard ratings are available from most manufacturers
- When making replacements, IT's will be proven technology from industry leaders in reliability. Application of equipment will be made to meet system operating demands. Installation will include testing and verification of operation.

Instrument Transformers: Implementation Milestones

Sparing Strategy

- Spare inventory for instrument transformers is completed annually to assure emergency stock will provide direct replacement ratings for 90% of all ratings and voltage levels in service today.

Capital

- By 4th QTR 2012 complete failure trend analysis for 2009, 10 & 11 emergency replacements to develop replacement strategies for non-PCB (polychlorinated biphenyl) IT's. Criteria will be developed based on this failure trending to predict optimum replacement time

Note: The ongoing Environmental PCB replacement program replaces approximately \$2-3M of IT's annually which currently makes up the majority of planned IT replacements. The environmental replacement program currently also meets several goals for condition based replacements.

Surge Arresters: Asset Criticality

Surge Arresters (SA) - Surge Protection:

- Surge arresters are passive protective devices that control over-voltages during system disturbances (lightning, faults, switchgear failures); and for normal operation where voltage transients (switching surges) can harm power system equipment like transformers.
 - Metal Oxide Surge Arresters (MOSA's) are the industry standard for both system reliability and more effective control of transient overvoltages. This includes insulation coordination which is a determining factor in BPA's minimum approach distances (MAD's).
 - Silicon Carbide (SiC) gapped arresters are no longer manufactured and obsolete in the industry. These devices are aging on the power system and are prone to moisture ingress that will cause the unit to dielectrically fail.
 - Rod gaps are a crude form of surge protection against lightning. Upon each operation a line fault is created that must be cleared by a breaker thus de-energizing the line. This momentary outage can contribute to SAIFI and SAIDI.

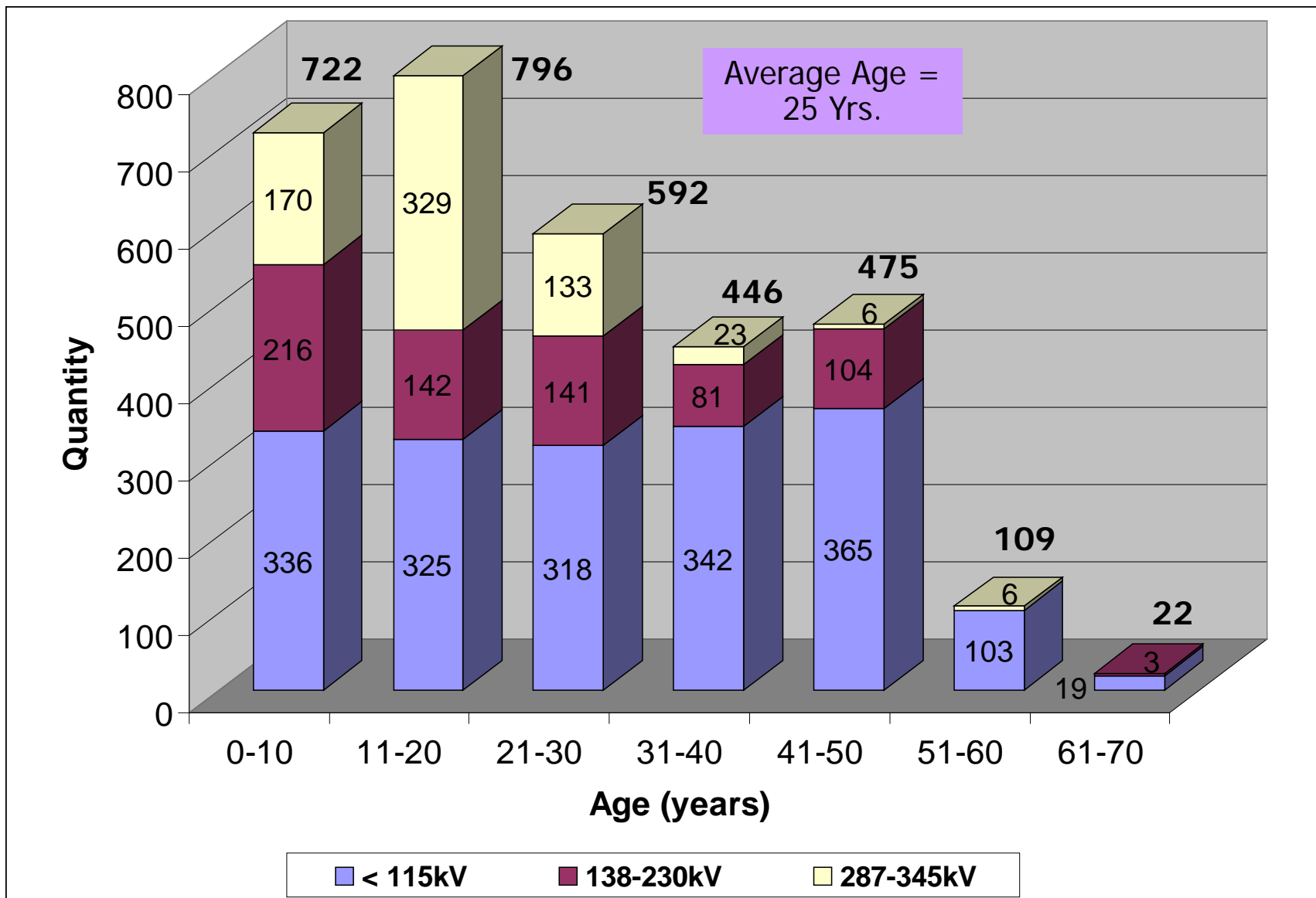
Surge Arrester Criticality:

- Surge Arrester criticality is determined by Transmissions priority ranking criteria of the equipment or line terminal they protect.
- Key Data:
 - Condition of SiC and MOSA arresters is based on age , Watts loss tests, and insulation (housing) performance (power factor tests and failure rates)
 - Rod gaps are replaced with MOV's to improve equipment protection and reliability. Rod gaps have a disadvantage compared to MOSA's when they operate by creating a line to ground fault to protect equipment. These faults at the very least increase momentary (< 1minute) line outages and require a breaker to clear the fault.

Surge Arrester: Performance Objectives

- **Performance Objective - Maintenance, All Surge Arresters and Rod gaps**
 - Measure(s):
 - Develop a new preventative maintenance guide (PMG) that covers testing, at least every 10 years of all surge arresters and rod gaps. Current PMG only covers surge arresters installed on transformers and not those installed on line terminals, reactors, capacitors and other others. Rod gaps currently have no inspection requirements but should be checked for proper air gap distance, arching damage to the tips, and corrosions of any parts including mounting brackets.
 - Rod gaps do not have a system equipment record (SER) but do need to be identified and tracked for replacement purposes. Develop an equipment type profile in CASCADE to allow tracking of rod gaps including the open gap distance they are set to in the field.
 - **End-Stage Target(s):**
 - 4th QTR 2012 Substation Maintenance and High Voltage Engineering SMEs will work with RCM to establish new maintenance inspections for surge arresters and rod gap testing and tracking.
- **Performance Objective – Replacements, All Surge Arresters and Rod Gaps**
 - Measure(s):
 - Develop a 10 year replacement plan for Silicon Carbide (SiC) gapped surge arrester targeting all those installed on 230 kV transformers and associated transformer low side arresters. Focusing first on arresters predating 1974, followed by those predating 1978. To reduce forced outages caused by arrester failures.
 - Develop a 10 year replacement plan for rod gap replacements to target and coordinate with critical 500 kV transmission lines, and planned line outages - particularly those where “bare-hand, live-line” maintenance techniques may be used. To reduce momentary outages thus increasing reliability and improved insulation coordination.
 - End-Stage Target(s):
 - By 1st QTR 2013 develop a 10 year replacement plan for SiC gapped arresters
 - By 1st QTR 2013 develop a 10 year replacement plan for rod gaps
 - By 3rd QTR 2014 50% of all remaining SiC gapped arresters installed on 230kV transformers have been replaced.
 - By 4th QTR 2015 20% of all remaining 500 kV line terminals with rod gaps will have been upgraded with MOSA's.

Surge Arresters: Age Demographics

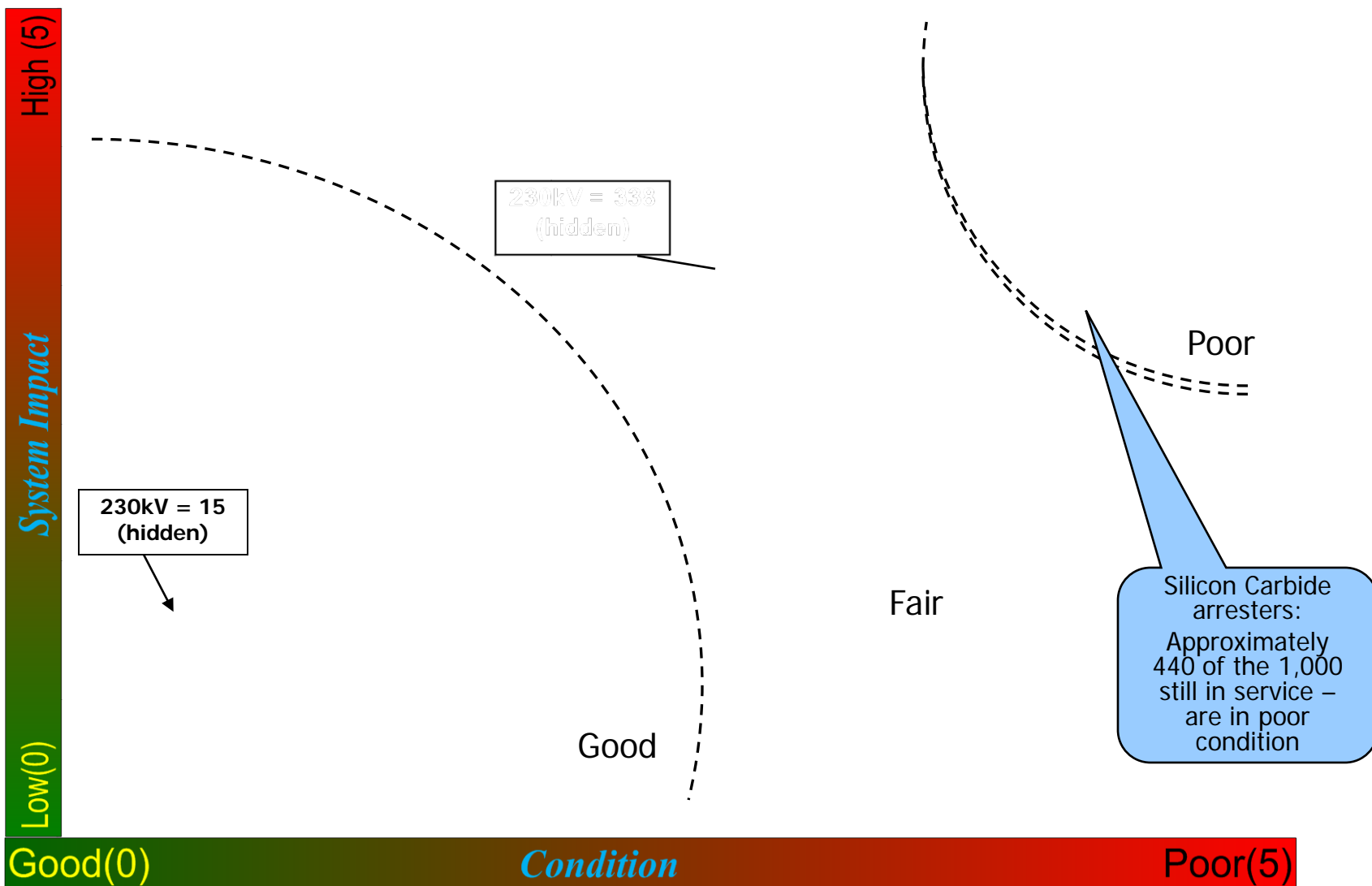


Surge Arresters: Failures

Surge arrester failure modes for Silicon Carbide (SiC) gapped arresters, Metal Oxide surge arresters (MOSA's)

- Housing seal failures - Silicon Carbide (SiC) gapped and metal oxide surge arresters (MOSA's).
- Transient overvoltage protection on lines – Replacing Rod Gaps with metal oxide surge arresters (MOSA's)
- Momentary outages (< 1 minute) – Replacing Rod Gaps with surge arresters (MOSA's) effectively eliminates momentary outages for the operation of a surge protective device. MOSA's do not create a line-to-ground fault like rod gaps when they operate.
- Surge arrester failures pose some risk to transformers or reactors during failure for two reasons:
 1. Porcelain housed arresters mounted directly on transformers may damage transformer bushings from debris. This risk is very low at BPA since all of the older SiC arresters have vents to relieve pressure during failure.
 2. Arresters typically fail in a short circuit mode thereby causing a line to ground fault at the transformer terminal. There is a low risk of damage and mainly a concern where transformer protection may be poorly coordinated (slow clearing of fuses or relays).

Surge Arresters: Assessing Risk



Surge Arrester: Strategy

The surge arrester and rod gap strategy is focused on four key areas:

- Performance monitoring and data analysis
- Maintenance and operations approaches
- Equipment standardization
- Maintaining the proper level of spare equipment and parts

Monitor/Record/Analyze Data

- Parameters to be monitored and recorded:
 - Watts loss, power factor
- Maintenance data to be recorded
 - Watts loss, power factor
 - Inspection of housing (porcelain, polymer) condition - external arcing, evidence of ruptured pressure disc.
 - Rod gaps - check for corrosion of parts and arcing damage of tips and proper gap distance
- Analyze
 - Failure rates by model, voltage, and design type

Optimal Replacement Window

- Surge arresters have an average expected life span of 35 years.
- Failed units are replaced – repairs are not possible.
- Standard ratings are available from most manufacturers
- When making replacements, MOSA's will be proven technology from industry leaders in reliability. Application of equipment will be made to meet system operating demands. Installation will include testing and verification of operation.

Surge Arresters: Strategy

The asset strategy for this equipment group is centered primarily on operating the equipment to functional failure and replacing equipment near its end of life.

- The equipment in this asset group has no parts that are either repairable or replaceable. The insulation system is permanently sealed and a seal failure constitutes arrester failure.
- Condition assessment and performance tracking for this asset group is highly dependent on patrol inspections (visual observation that is recorded) and relatively infrequent 7-10 years testing when either transformers or bus outages are taken.
- Monitoring (on line recording/measurement) of electrical or functional characteristics is not practical due to the cost of monitoring vs. equipment value. Some utilities use counters on their surge arresters but the technology to date does not yet provide very accurate or valuable results.
- The best performance indicators are in-service failures that show seal degradation trends or end of life of the SiC or MOSA materials.

Surge Arresters: Implementation Milestones

Sparing

- Evaluation of spare inventory for surge arresters was performed in 2011 to provide replacements for 100% of all ratings and voltage levels in service today.
- EMS has a minimum of 3-6 spare units for each standard arrester size used on the system as the result of an effort in 2011.

Capital

- By 2018 Replace 500 kV rod gaps on all 500kV line terminals that will be worked hot using live-line, bare hand maintenance techniques.
- By 2019 Replace 95% of all remaining 230kV SiC gapped arresters, including associated low side arresters for arresters installed on transformers and reactors.
- By 2021 Replace 95% of all remaining 69 – 161kV SiC gapped arresters including associated low side arresters where they are installed on transformers.

Executive Summary

What equipment is covered?

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Equipment Strategies

- Power transformers and reactors
- Switchgear
- Shunt capacitors
- Instrument transformers and surge arresters
- **Station auxiliary**
- Substation bus & structures



What will it cost?

Program Accomplishments FY10 & FY11

Station Auxiliary: Asset Criticality

Station Auxiliary - Batteries & Chargers, SS Transformers, Engine Generators, SS Cabling, Grounding

- Lower voltage equipment provides AC station service (operating) power for control houses, yard lighting, control and data acquisition systems, security systems, and communication systems.
 - DC Control Batteries - provide backup DC control power for protective relays.
 - AC Power – required for normal operation of HV equipment - for control cabinets, breaker tank heaters, transformer cooling fans, and station yard power for maintenance and construction AC power for Non Electric Plant (NEP) facilities within a substation including maintenance buildings, warehousing and similar NEP facilities that may be co-located within Substations.
 - Engine Generators, Transfer Switches – provide back-up power for loss of the primary SS power source

Station Auxiliary - Criticality

- The criticality of Station Auxiliary Assets is determined by Transmissions priority ranking criteria combined with the level of redundancy or back-up power sources (local utility, engine generators).
- Key data for this program area:
 - Station Auxiliary equipment condition is based on the age, failure rates by type, service conditions and environment (SS loading, air born contamination, underground/water conditions, extreme temperatures)
 - Failure rates and reduced capacity for DC Control Batteries
 - Station Service Transformers and buried SS Cables - Insulation degradation due to loading, weather
 - SS transformers and buried SS cables - Insulation degradation due to electrical effects - transients (lightning, switching transients, ground faults)

Station Auxiliary: Performance Objectives

Station Auxiliary: Auxiliary equipment provides operating power for all substation equipment and most non electric plant (NEP) facilities within a substation. The majority of this equipment does not have maintainable or repairable parts and is operated to failure or near failure. Station Service transformers are permanently sealed and older units may have PCB's that cannot be measured/detected until a leak or failure occurs.

- Station Auxiliary Performance Objectives: Provide reliable operating power to substation equipment to minimize reliance on back-up and secondary power sources.

DC Control Batteries:

- **Measures** - Improve overall replacement rate and timeline for DC control batteries (both failed and banks with reduced, $\leq 80\%$, capacity)
- **End Stage Targets:**
 - Perform emergency control battery replacement within 4-6 months for installations that do not require control house expansions or modular enclosures
 - Perform 12-15 scheduled control battery replacements per year due to system needs and asset condition
 - Start 2 year design / build on all new planned control battery replacements starting in FY13

AC Station Service (SS) equipment: transformers, cables, transfer switches, AC service panels:

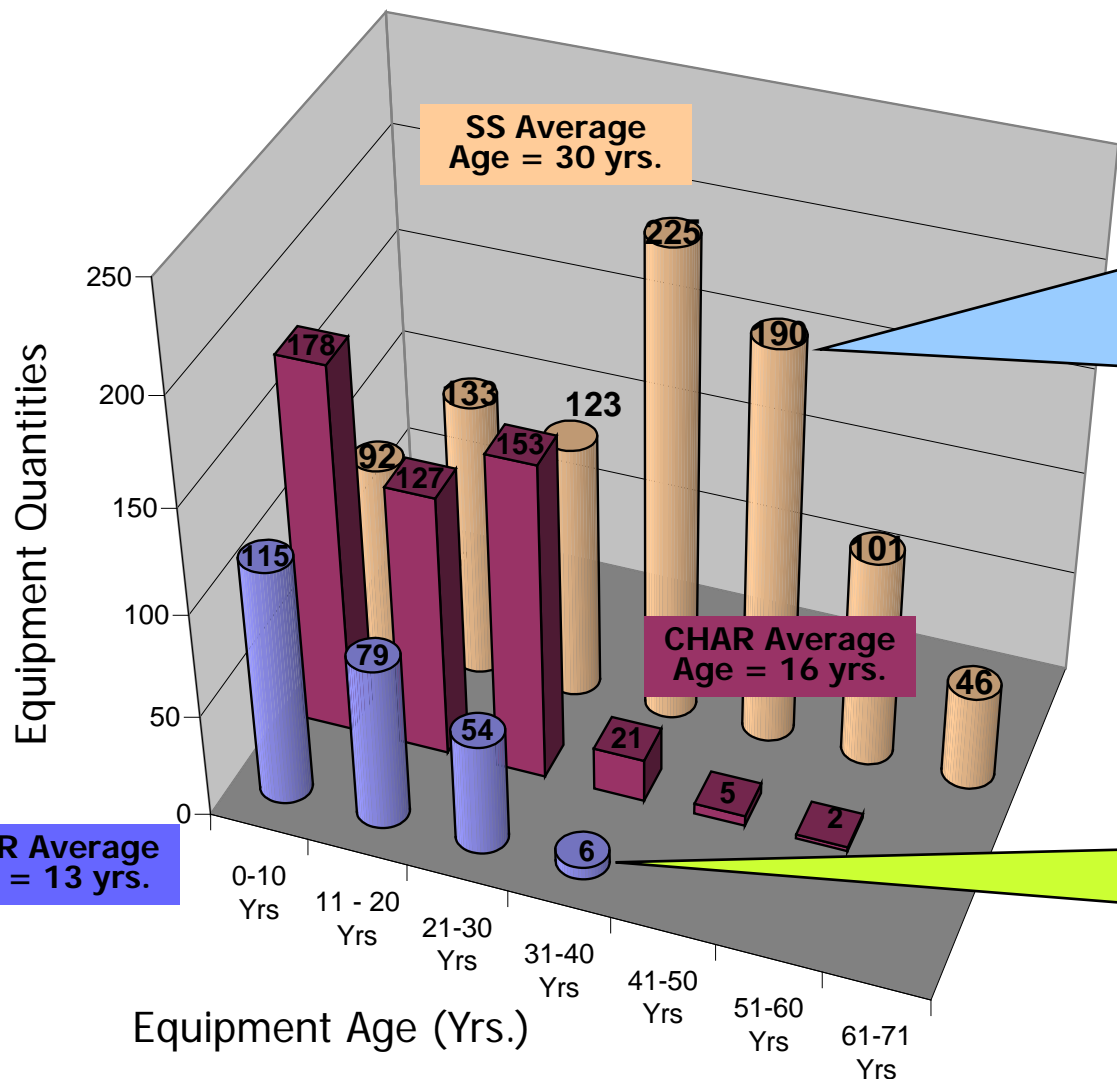
- **Measures** – Improve long-term SS reliability and safety by targeting “whole system” station service equipment replacements/upgrades. Includes capacity expansions for future growth in stations where likely. Equipment upgrades include transformers, cables, AC panel upgrades, transfer switch upgrades, replacing single phase switches w/three phase/group operated switchgear.
- **End Stage Targets** – Complete 3–5 major SS replacements/upgrades over the next 3 years – focusing on the top 5% of critical SS with both capacity and safety deficiencies identified in the Submaintenance 2007 report and Facilities Asset Management (FAM) Facilities Report.

Engine generators:

- **Measures** – Improve EG reliability and safety by replacing/upgrading systems in the top 5% of station service rated deficient.
- **End Stage Targets** - Upgrade 3-5 permanently installed EG's sets and fuel systems annually – based on priorities set in the Submaintenance 2007 report and Facilities Asset Management (FAM) Facilities Report.

Current State of the Assets

■ DC Control Batteries = 254 ■ Chargers = 486 ■ Station Service TX's = 910 ■ Total = 1650



Typically "run to failure" replacement strategy.

However, planned replacements are needed to eliminate older PCB contaminated units and to manage failures "emergency replacements" avoid accumulation of failures (peaks) and overloading of resources.

Expected Life for Batteries is 15- 20 years. Resource constraints and long lead times have created a backlog in both emergency and planned battery replacements.

Station Auxiliary: Strategy - Optimal replacements

Station Auxiliary equipment have varying life spans - at the lowest end of the spectrum are DC control batteries and chargers. Station service transformers and transfer switches have the highest expected lifespan. Engine generators and power cables tend to fall in the middle to high end of the spectrum.

Optimal Replacement Window – AC Station Service (SS) Equipment - Transformers, Power Cables, & Service Panels

- SS- Due to varying sizes 2460 VAC up to 34.5 kVAC; dry type and oil filled SS transformers vary in lifespan from 25–45 years depending largely on insulation type with oil filled typically lasting longer.
- Power cables vary from 25-35 year depending on insulation type, environmental conditions, and loading (current) of the cable.
- Service panels may last 25-35 years depending on the availability of replacement air circuit breakers (ACB) and loading – station loads usually outgrow the panels' capacity to add new circuits and carry the additional current.

Optimal Replacement Window – DC Control Batteries

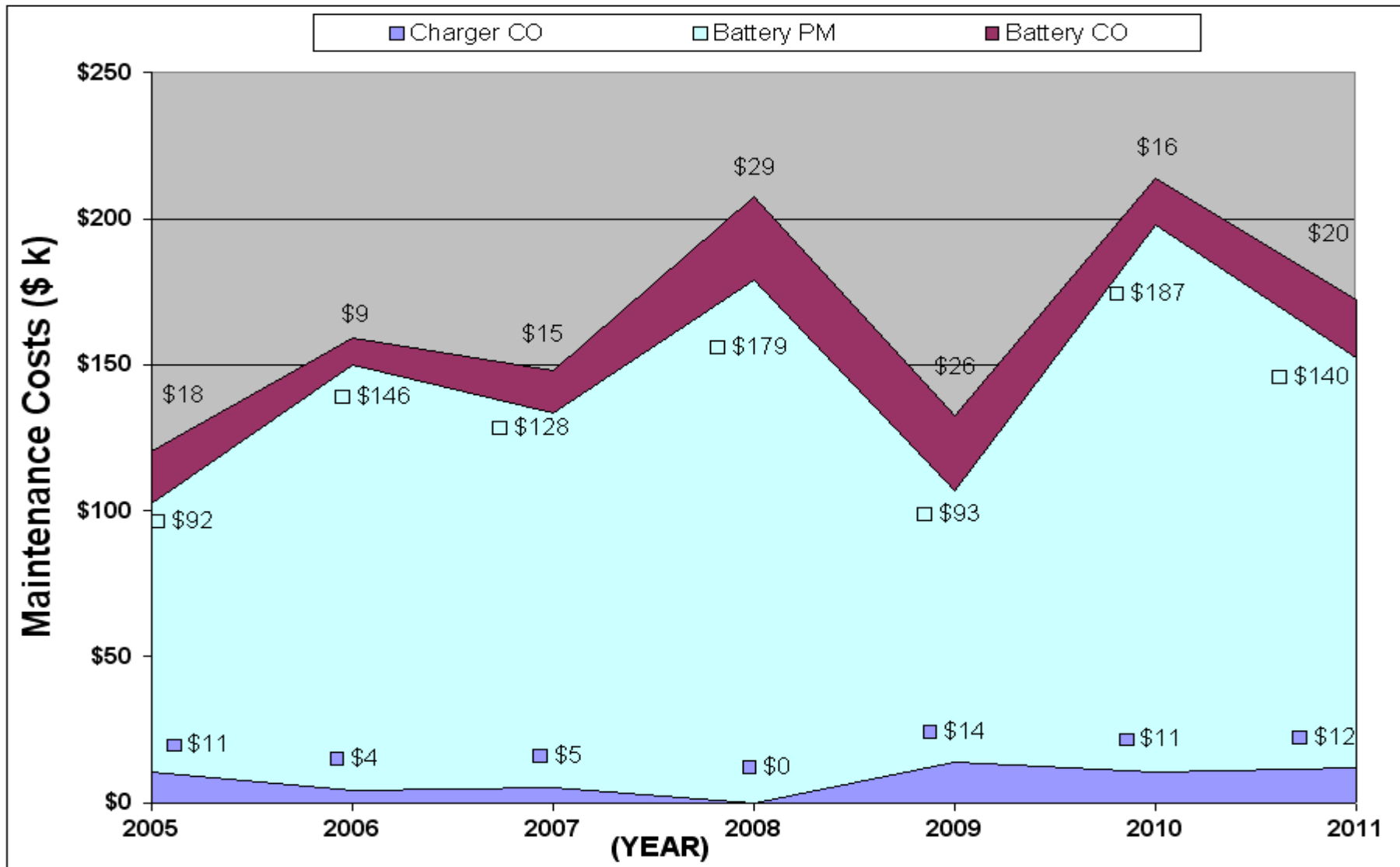
- NiCad Batteries → 25 years
- Vented Lead Acid Batteries → 15-25 years
 - Lead Antimony → 15 years
 - Lead Selenium → 20 years
 - Lead Calcium → 20 years
 - Plante → 25 years
- Valve Regulated lead Acid Batteries → 10 years

Optimal Replacement Window – Engine Generators (EG's)

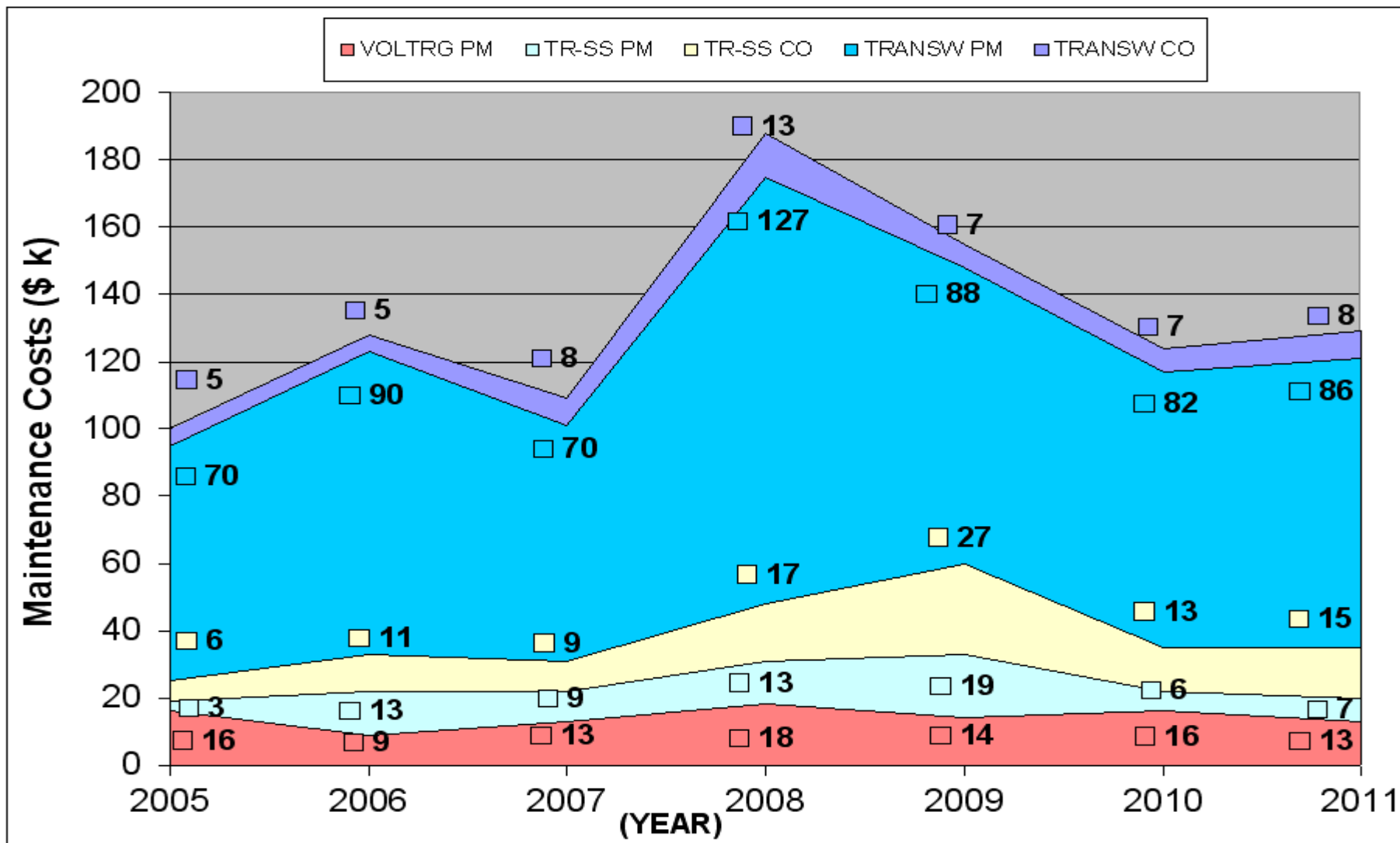
- Engine generators, permanently installed in stations requiring redundant SS sources, can last 20–30 years depending on service duty, environmental conditions, and fuel type. EG replacements may include upgrading or replacement of fuel system components, transfer switches, and housing associated with the EG.
- When making station auxiliary replacements they will be replaced to meet current electrical industry standards for the specific equipment groups.

Maintenance Costs – Control Batteries & Chargers

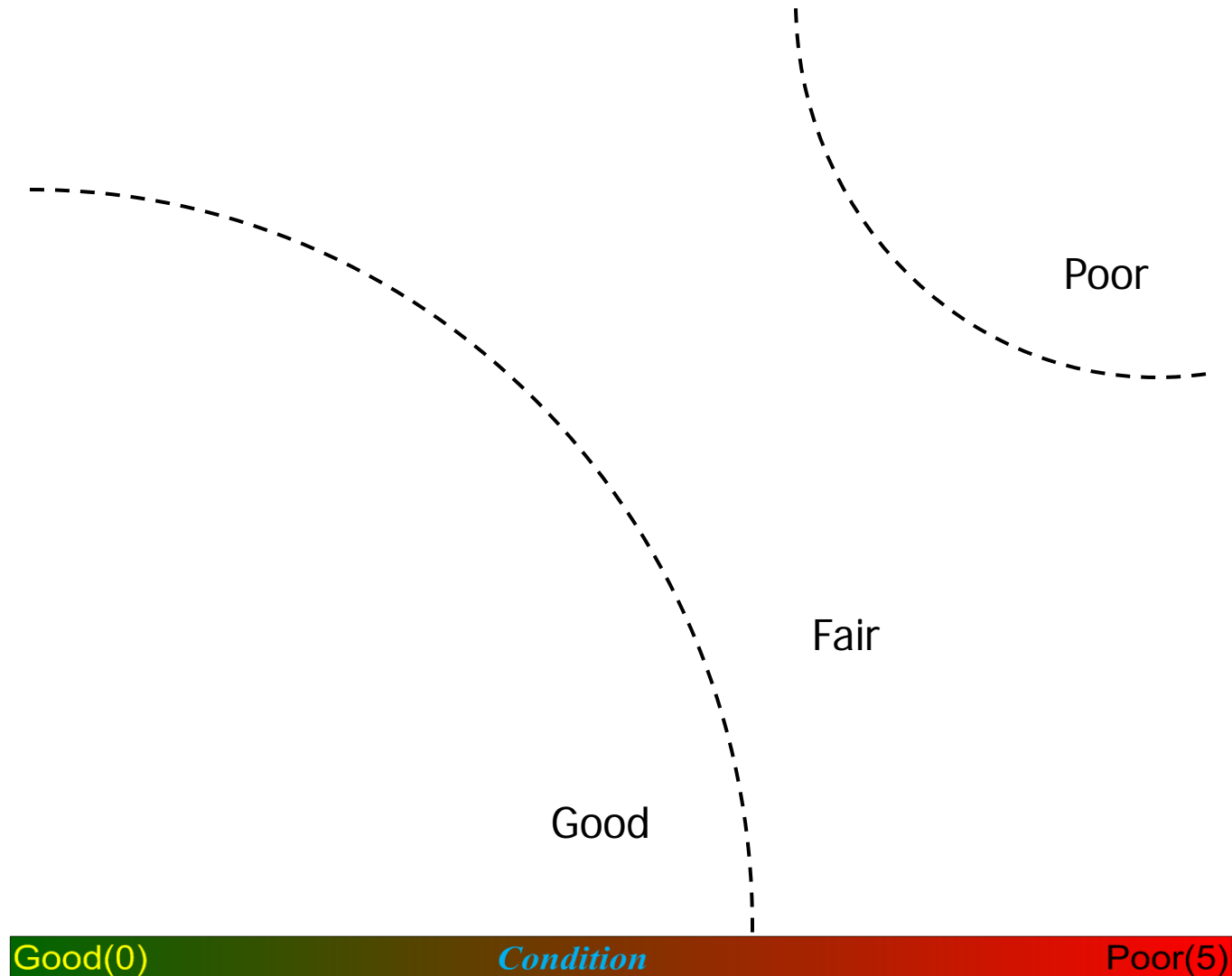
(Excludes Communication Batteries)



Maintenance Costs – Station Service Transformers, Voltage Regulators, & Transfer Switches



Station Auxiliary: Assessing Risk



Station Auxiliary: Strategy

- The asset strategy for this equipment group is centered primarily on replacement vs. maintenance. The data requirements are focused on inspection results, a small amount of testing or monitoring, and failure trending. Most of the equipment have only a small number of components that can be maintained (replaced or repaired).
- Station auxiliary reliability is based on two major components:
 1. Spares – stocked in BPA warehouses or through purchase agreements with local vendors.
 2. Redundancy or back-up power sources: Alternate SS (i.e. local utility) backs-up BPA SS; multiple SS sources (redundancy) in some stations can provide (not necessarily 100%) back-up; engine generators (portable or permanently installed) back-up SS supply's.
- Replacement priorities are currently based on two major reports completed in 2007 and 2010 that highlight deficiencies in three major areas - safety (i.e. National Electric Safety Code -NESC), condition factors, and inadequate capacity. The surveys and corresponding reports were conducted by independent contractors well versed in "distribution" electric systems. BPA will continue to incorporate this type of expertise for the evaluation of station service assessments. Historically BPA has concentrated it's expertise in the design, operation, and maintenance of "transmission" facilities with much less emphasis on the lower voltage "distribution" type facilities that do not carry commercial power but provide secondary or supporting power to the main infrastructure. The utilization of outside expertise will continue to augment BPA's ability to provide reliable station auxiliary power.
- Implementing New Standards: In 2010 new standards for SS and EG designs and documentation were issued to help remedy various station auxiliary issues outlined here: Significant portions of this asset group are replaced under expense programs and this has, over the years, led to non-standard installations and undocumented modifications/expansions. Independent contracting for replacement of some SS electrical equipment and engine generators has also contributed to this problem.

Station Auxiliary: Strategy (2)

Station service transformers & cables:

- Inspections - Thermovision, visual (oil leaks), electrical & insulation tests
- Monitoring/testing – Station service supply voltage, grounding (dc grounds, neutral shift)
- Analyze
- Monitor/Test - Substation Auxiliary Parameters to be monitored and recorded:
 - Test/Measure – SS TX Power factor, winding ratios, etc. (as required by PMG's) Voltage & Current measurements where applicable and feasible
 - Measure - Thermovision
 - Inspection - Oil leaks, broken/damaged bushings
 - Cables – voltage, resistance, connector condition on URD/insulated cables, grounds

DC control batteries:

- Inspections – battery leaks, bulges, temperature, vapors
- Monitoring/testing – voltage, battery capacity (load test or impedance test), fluid – specific gravity (as applicable)
- Maintenance data to be recorded
 - For electrical equipment – DC Battery – Cell failures/replacements and charger replacements/failures
 - Oil Leakage rates and mitigation efforts

Engine Generators:

- Inspection/Monitoring/testing
 - Hours of operation for EG's
 - Voltage stability, output capacity (loading), fuel consumption/emissions, start-up

Analyze – All SS Equipment

- Failure rates/trends by model, voltage, and design type

Station Auxiliary: Implementation Milestones

- By 4th QTR 2012 complete the 3 remaining carry-over replacements of 2009 & 2010 battery and chargers projects.
- By 4th QTR 2014 replace the two remaining DC control batteries that are beyond 30 years of age and thus beyond their expected useful life.
- By 4th QTR 2015 complete 6 AC station service projects with “systems” ranked in “poor” condition based on safety, capacity & condition factors.

Executive Summary

What equipment is covered?

Strategic environment & drivers

Strategies

Process improvements

Equipment Strategies

- Power transformers and reactors
- Switchgear
- Shunt capacitors
- Instrument transformers and surge arresters
- Station auxiliary
- Substation bus & structures



What will it cost?

Program Accomplishments FY10 & FY11

Substation Bus & Structures: Asset Criticality

Substation Bus & Structures – Bus, Insulators, Towers, and Supports

- Includes electrical and non-electrical supporting infrastructure for HV electrical equipment in substations: Dead-end (line termination) transmission towers; supports and foundations for disconnect switches, instrument transformer, electrical bus, etc.; substation bus and insulators, seismic hardening, fuel storage systems and enclosures for engine generators.
- These supports and structures provide the required electrical clearances or spacing between energized equipment (phase-to-phase); energized equipment to ground, and safe working distances for personnel and HV electrical equipment to work and operate safely.

Substation Bus & Structures – Criticality

- The criticality of Substation Bus & Structures is determined by Transmissions priority ranking criteria. The failure of these items can cause electrical faults and damage to other substation equipment or personal injury if failures occur while workers are present.

Substation Bus & Structures: Performance Objectives

Substation Bus & Structures: The Substation Bus & Structures is a new replacement program that requires development of performance factors. There has been a small program for the past 5 years targeting the upgrade of bus connections on critical equipment to seismic connections.

- **Substation Bus Performance Objective:** Capital & Maintenance – Replace substation rigid or flexible bus that is underperforming as follows:
 - **Measures:**
 - Upgrade underrated Bus – substation bus or bus sections that are not rated for the continuous current (bottleneck)
 - Bus Hot spots – Thermovision (bus connections), high resistance - Poor electrical contact (electrical compound –NO-OX problems)
 - Corrosion (steel & copper bus), galvanic corrosion
 - Fitting fatigue, ice damage, bad compression for pressed fittings (mechanical failure) – visual inspection;
 - Seismic zones combined with system critical equipment
 - **End Stage Targets:**
 - Replace all remaining steel bus by 2016.
 - Replace all cracked pressed bus fittings within one year of discovery or sooner depending on severity
 - Upgrade 10% of all remaining non seismic bus connections annually

- **Structures Performance Objective:** This equipment is subject to predominantly structural and mechanical failures modes and requires performance criteria to be developed
 - **Measures:**
 - Structural condition – corrosion, metal damage – criteria needed
 - Foundation – spalling, cracking, uneven settling/frost heave (site conditions) – criteria needed
 - **End Stage Targets:**
 - 1st QTR 2013: Develop Measurement/Inspection criteria for assessing condition of structures, supports & foundations
 - 3rd QTR 2013: Develop repair criteria and a coordinated replacement approach for structures and footings to minimize station service interruption and cost.

Substation Bus & Structures: Assessing Risks

Substation Bus & Insulator Failure Modes

- Bus – Overheating of older steel & copper bus due to increased loads, corrosion, deteriorating fittings - issues due to age and limited manufactures of replacement fittings for steel & copper bus.
- Bus – Aluminum pressed fittings – failures due to degradation of the filler compound, ingress of moisture, cracking due to moisture ingress and subsequent freezing, internal corrosion leading to high resistance connection, heating/annealing, stretching & thinning of conductors
- Porcelain Insulator failure - due to tracking (electrical), cracking, pin & cement failure between sheds
- Polymer insulator failure – Loss of hydrophobicity (ability to shed water and contaminants) leads to tracking, arcing, and loss of insulation quality. Separation between polymer and end fittings due to high voltage electric field stresses.

Substation Bus: Strategy

The asset strategy for substation bus centers around periodic inspection and replacement of individual fittings or small bus sections when a mechanical or electrical failure occurs. Bus that is found to be underrated will be upgraded to meet the minimum continuous current ratings (path rating). Planned replacements of large bus sections or bus in multiple bays may be required for older steel or copper bus where replacement fittings and bus are no longer available.

Optimal Replacement Window – Bus & Insulators

- Substation bus has a reported 45 year expected life span based on accounting practices but routinely exceeds that figure. Very few stations at BPA still have mostly steel or copper bus. Those remaining are plagued with corrosion issues; overheated connections; and connectors prone to breakage.
- When making bus and fitting replacements the installations shall meet all applicable material and workmanship standards. In particular bus fittings shall be selected to avoid galvanic corrosion (when metals of dissimilar material come in contact with one another). All fittings whether bolted or pressed shall be the appropriate type and amount of conductive/filler compounds to assure good (low resistance) long lasting electrical connections.

Substation Bus - Asset strategy development needed - Inspect/Record/Analyze Data

- There are presently no centralized systems in place to record data associated with the inspection, condition, and failure of these assets. These facilities have no unique identifiers. Some of these components are capitalized when replaced and others are expensed.
- A method of component identification and asset health & condition data storage is needed.

Substation Insulators: Strategy

The asset strategy for insulators centers around periodic inspection and replacement of individual insulators at the time of failure. A high percentage of failures may drive planned replacements of a large population of insulators where degradation due to age or poor manufacturing is causing excessive failures and reducing reliability.

Optimal Replacement Window – Bus & Insulators

- Porcelain insulators have an expected lifespan of 35 years and routinely exceed that figure.
- Polymer (non ceramic) insulators, up to this time, are not used in AC substations. Their expected life span is currently 25 years and only a few vendors have had polymer insulators in continual service for that many years.
- When insulators are replaced they shall meet all applicable industry standards for electrical insulation strength (flashover, puncture, water/contamination shedding, etc.) and mechanical strength for the intended application.

Insulators - Inspect/Record/Analyze Data

- There are presently no centralized systems in place to record data associated with the inspection, condition, and failure of these assets. These facilities have no unique identifiers. Some of these components are capitalized when replaced and others are expensed.
- A method of component identification and asset health & condition data storage is needed.

Substation Bus & Structures: Assessing Risks

Substation Structures & Foundations – Failure Issues

This is a relatively new Asset group in terms of treating these facilities in formalized program. This asset group currently lacks a tracking method or system and condition assessment criteria. The condition of these assets were superficially addressed in a report published in 2007 focusing on Substation NEP and Supporting infrastructure. The most significant finding regarding structures and foundations was that almost 1/3 of the facilities (stations) were at or exceeded 50 years of age and were exhibiting distinct signs of age related degradation.

- Steel supports and towers – Corrosion, rust, metal fatigue, broken bolts, bent or twisted members
- Steel – Assess repair options: replacing individual members, adding structural reinforcement
- Foundations – Spalling (flaking, chipped, pitted) may be repaired/patched to avoid further degradation of concrete and foundation failure due to loss of rebar (rust/corrosion)
- Foundation – Cracking: mild superficial surface – may be repaired/patched to avoid further degradation (water ingress/ice); severe- due to rebar or concrete failure (replace)
- Foundation – Uneven settling, frost heave – can damage electrical equipment particularly insulator failure, and misalignment of disconnect switches.

Critical Takeaways:

1. While asset groups such as SPC, PSC, AC SUB's (electrical), and Transmission Lines have dedicated staff that work, at least part time, on maintenance standards and condition assessment criteria very few resources currently exist to focus on Substation Structures & Foundations condition assessment.
2. Clear and consistent condition assessment criteria needs to be developed to help make replace vs. maintain (repair) decisions.
3. Assessment methods and a data repository needs to be developed to begin recording and tracking condition data and repairs.

Bus & Insulators: Strategy

Bus & Insulators - Inspect/Record/Analyze Data

- Key data for this program area **Inspect/Record/Analyze Data** :

Bus & Insulators

- Visual and Thermovision inspection of bus condition (corrosion, high resistance hot spots, cracking or fatigue of fittings & jumpers, conductor separation)
- Bus & Fitting types – Copper, Steel, Aluminum; bolted, welded, pressed
- Visual and Thermovision inspection of insulators (cracking, tracking, corona, water shedding).
- Insulator age
- Site conditions for Insulators – contamination (industrial, agricultural); weather – precipitation, icing, UV

Structures, Supports & Foundations Condition

- Visual and physical inspections to ascertain condition of structures (corrosion, cracking, metal fatigue); foundations (cracking, crumbling, frost heave, settling)
 - Site conditions – Soil type and condition, frost depth, seismic zone, climate
 - Galvanic corrosion of structures
1. Clear and consistent condition assessment criteria needs to be developed to help make replace vs. maintain (repair) decisions for this asset group.
 2. A method or system needs to be developed (perhaps in CASCADE) to begin recording and tracking condition data and repairs. This may need to begin with just a station by station assessment.
 3. Replacement methods, techniques, and options need to be developed to address the highly disruptive nature of replacing structures and foundations in substations while minimizing disruption to service

Optimal Replacement Window

- Structures and foundations have an expected lifespan of 45 years and many cases exceed that figure.
- Repair and reinforcement options need to be developed and applied consistently to provide short term mitigation of potential failures that can impact reliability, damage equipment, or cause injury if workers are present
- When making concrete and structure replacements they will be replaced to meet current seismic standards as applicable. In addition all materials shall meet the applicable quality standards for materials, workmanship, and installation methods.

Structures & Foundations: Strategy

Structures & Foundations - Inspect/Record/Analyze Data

Critical Takeaways - Inspect/Record/Analyze Data:

1. Clear and consistent condition assessment criteria needs to be developed to help make replace vs. maintain (repair) decisions for this asset group.
2. A method or system needs to be developed (perhaps in CASCADE) to begin recording and tracking condition data and repairs. This may need to begin with just a station by station assessment.
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- When making concrete and structure replacements they will be replaced to meet current seismic standards as applicable. In addition all materials shall meet the applicable quality standards for materials, workmanship, and installation methods.

Seismic Bus Riser Replacements

- 500kV seismic bus riser replacements are 25% complete
 - Remaining 75% will be completed 4-5 per year according to the capital forecast. This work is coordinated with TLM scheduled line outages.

Structures & Foundations: Implementation Milestones

- By 4th QTR 2012 develop “emergency replacement” template for structure and foundation replacements to address substation steel structure corrosion and failing foundation problems.
- By 3rd QTR 2012 complete the following:
 1. Criteria and processes to evaluate how and when substation structures should be repaired vs. replaced – this will become part of the next Bi-annual asset strategy.
 2. Alternative methods or designs for major substation bus replacements to allow continuity of service, i.e. mobile substation use during construction; temporary bus support systems; yard expansion/new bay construction in lieu of replacing existing bays; new structure designs alternatives/standards for major replacement of older structures, etc..
- By 4th QTR 2012 complete technical evaluation on structures at Ashe Substation under the new corrosion assessment criteria and recommend a repair/replacement timeline based on the findings.
- By 1st QTR 2013 complete the bus pedestal replacement at Satsop Substation.

Executive Summary

What equipment is covered?

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Strategies

Process improvements

Equipment Strategies

- Power transformers and reactors
- Switchgear
- Shunt capacitors
- Instrument transformers and surge arresters
- Station auxiliary
- Substation bus & structures

 **What will it cost?**

Program Accomplishments FY10 & FY11

Forecast Planning Levels

Momentum Strategy

Historically capital replacements have been based on relatively short planning cycles, 3-5 years that dealt primarily with highly visible failure issues or chronic maintenance problems. The philosophy was predominantly an operate to failure approach. The legacy strategy was weak in long term tracking and trending failures rates for equipment and parts for all but the highest value equipment. Repair history, failure rates, and analysis was largely uncentralized and prioritization of replacements was mostly subjective due to lack of consistent supporting data.

This historical approach led to three significant issues that this strategy aims to remedy

1. Periodic spikes or peaks in equipment failures requiring emergency replacements. The Run to Failure approach is reasonable and cost effective when correctly applied but when misapplied leads to inefficient use of resources (i.e. maintenance & construction) and risks both reliability and the timely completion of planned work.
2. Periodic accumulation or bow wave of urgent replacements making it difficult to coordinate (ramp-up) financial and staffing resources needed to accomplish the required replacements.
3. Increased demand on maintenance and supply chain resources to maintain, repair, stock, contract for services (emergency & planned) and acquire parts to continue repairing equipment well beyond it's peak life cycle.

Historical Funding Levels – Capital Replacements

The table below provides an estimation of past funding levels for replacements that today fall into the AC Sustain Asset program. Past reporting practices may have captured some system replacement projects under an “upgrades and additions” capital program and, in the case of smaller equipment such as instrument transformers, surge arresters and station service equipment, may have been reported as expense rather than capital.

AC Sustain (Replacement of High Voltage AC Substation Facilities) - Historical (Direct capital expenditures in nominal dollars)											
Major Equipment Categories	FY2001	FY2002	FY2003	FY2004	FY2005	FY2006	FY2007	FY2008	FY2009	FY2010	FY2011
Circuit Breakers & Switchgear (4454)	204	8,104	18,487	12,246	7,384	8,955	6,352	5,981	7,609	5,038	5,614
Transformers & Reactors (5131)	375	183	220	1,900	-1	10	292	5,117	30,139	1,679	616
SUB Capacitors - Shunt (5517)	0	0	78	8,133	762	60	2,134	30	62	425	93
SUB PT/CT/CVT & Arresters (5140)	0	0	56	144	55	1,816	618	742	514	802	1,286
SUB Low Voltage Station Auxiliary (5679)	55	258	525	493	44	49	1,528	3,592	2,230	2,442	3,437
SUB Bus & Structures (5680)	39	153	7	387	105	-4	506	1,526	551	498	396
AC Sustain Totals	674	8,698	19,373	23,302	8,349	10,885	11,430	16,989	41,104	10,885	11,442

Notes:

- Changes in financial reporting occurred in the 2003/4 timeframe that may affect the accuracy of the data before and during this transition period. Mainly due to changes in capital vs. expense reporting.
- In 2009/10 the addition of many new capital replacement equipment categories for financial reporting and the transfer of projects from “miscellaneous” and “upgrades & additions” categories to the newer more specific equipment categories may also affect the data accuracy.
- Negative numbers show where projects from previous years were completed and under budget; and the cost of any new projects in that same year were offset by the returned funds.

Forecast Planning Levels – Capital Replacements

Momentum Plan funds replacements at an increased rate compared to the past 10-12 years. Increases in funding levels target specific assets within the major equipment categories that can no longer be maintained due to end of life, lack of spare parts, diminishing vendor support and significant increases in maintenance costs for certain equipment types and models.

Substation Replacements Program Totals - 10 Year Forecast (03/01/2012)

AC Sustain (Replacement of High Voltage AC Substation Facilities) - Forecast Planning Levels (direct capital expenditures in FY 2011 dollars)

	FY2012	FY2013	FY2014	FY2015	FY2016	FY2017	FY2018	FY2019	FY2020	FY2021
Transformers & Reactors (5131)										
Transformers	194	8,783	8,486	9,028	4,050	3,847	5,518	3,684	4,050	3,847
Reactors	0	34	190	153	3,306	0	153	3,306	0	153
Transformer Power FUSES (Maint/Obsolete)	294	756	1,171	380	0	0	0	0	0	0
Transformer GIC Monitor Replacements	369	622	210	210	0	0	0	0	0	0
Carry Over	207	42	0	0	0	0	0	0	0	0
TX/RX Totals (\$K)	1,064	10,237	10,057	9,771	7,356	3,847	5,671	6,990	4,050	4,000
SUB CVT/PT/CT & Arresters (5140)										
Subtotal CVT/PT/CT Replacements(\$K/1)	109	684	684	684	684	684	684	684	684	684
Subtotal Surge Arresters	0	435	2,191	1,483	785	824	865	909	954	1,002
Carry Over	571	126	0	0	0	0	0	0	0	0
IT's & Arrester Totals (\$K)	680	1,244	2,875	2,167	1,469	1,508	1,549	1,593	1,638	1,686
Circuit Breakers & Switch Gear (4454)										
Breakers	7,127	7,206	7,546	5,336	10,806	9,466	6,645	6,645	6,645	6,645
Circuit Switchers	3,097	2,863	990	3,313	4,263	3,633	3,036	2,846	2,939	3,041
Disconnects	703	94	259	657	1,397	1,447	1,395	1,152	705	705
Carry Over	2,951	4	0	0	0	0	0	0	0	0
Switchgear Totals (\$K)	13,878	10,167	8,795	9,306	16,466	14,546	11,076	10,643	10,289	10,391
SUB Capacitors - Shunt (5517)										
Fuseless Shunt Capacitor Upgrades (Arrester Additions)	0	0	0	0	0	0	0	0	0	0
Shunt Bank Replacement	0	141	1,077	0	0	0	0	0	0	0
Carry Over	114	0	0	0	0	0	0	0	0	0
Shunt Capacitor Subtotals (\$K)	114	141	1,077	0	0	0	0	0	0	0
SUB Low Voltage Station Auxiliary (LVSA) (5679)										
DC Station Control Batteries Subtotal (\$K)	1,410	1,577	133	1,125	1,236	1,343	1,331	1,331	1,331	1,331
Station Service	694	1,260	1,431	2,757	3,513	3,734	3,628	3,167	2,838	2,833
Carry Over	3,418	234	0	0	0	0	0	0	0	0
Low Voltage Auxiliary Totals (\$K)	5,522	3,071	1,564	3,882	4,749	5,077	4,959	4,498	4,169	4,164
SUB Bus & Structures (5680)										
Bus, Structures & EG's Subtotal(\$K)	204	516	2,176	4,151	4,857	5,745	7,727	9,089	8,768	7,772
Seismic Subtotal (\$K)	450	396	396	396	396	396	396	396	396	396
Carry Over	19	83	0	0	0	0	0	0	0	0
Sub & Structures Subtotal (\$K)	673	995	2,572	4,547	5,253	6,141	8,123	9,485	9,164	8,168
Substation Totals (\$K)	\$ 21,931	\$ 25,855	\$ 26,940	\$ 29,673	\$ 35,293	\$ 31,120	\$ 31,378	\$ 33,208	\$ 29,310	\$ 28,409

Notes:

1 Various instrument transformers that may contain PCB contaminants but cannot be tested (permanently sealed) are being replaced under the Environmental (KEP) Capital Replacement program for 2010 - 2016. The KEP replacement forecast is not part of the SUB AC forecast above. The SUB AC replacement targets largely overlap the KEP targets which allows the current KEP program to meet the goals of both the AC Sustain and Environmental programs.

Risks of constrained budget

Potential impacts from not fully funding the proposed asset strategy

- Asset Performance Objectives and Targets
 - Corrective maintenance costs will rise or remain high on aging and equipment in poor health

- Asset Failure
 - Vendor support for some equipment is becoming scarce or non reliable
 - May cause more emergency replacements of circuit breakers and circuit switchers
 - Will risk a “run to failure” approach on some assets thus replacing under emergency conditions at higher cost than a planned replacement

- Other Risks
 - Retaining an inventory of obsolete parts for equipment that is scheduled to be replaced increases warehousing costs
 - Vendor support for spare parts is becoming scarce or non reliable

- Replacement Backlogs
 - Would continue to keep obsolete and aging equipment in service thus affecting reliability.

AC Substation – Momentum Maintenance Costs

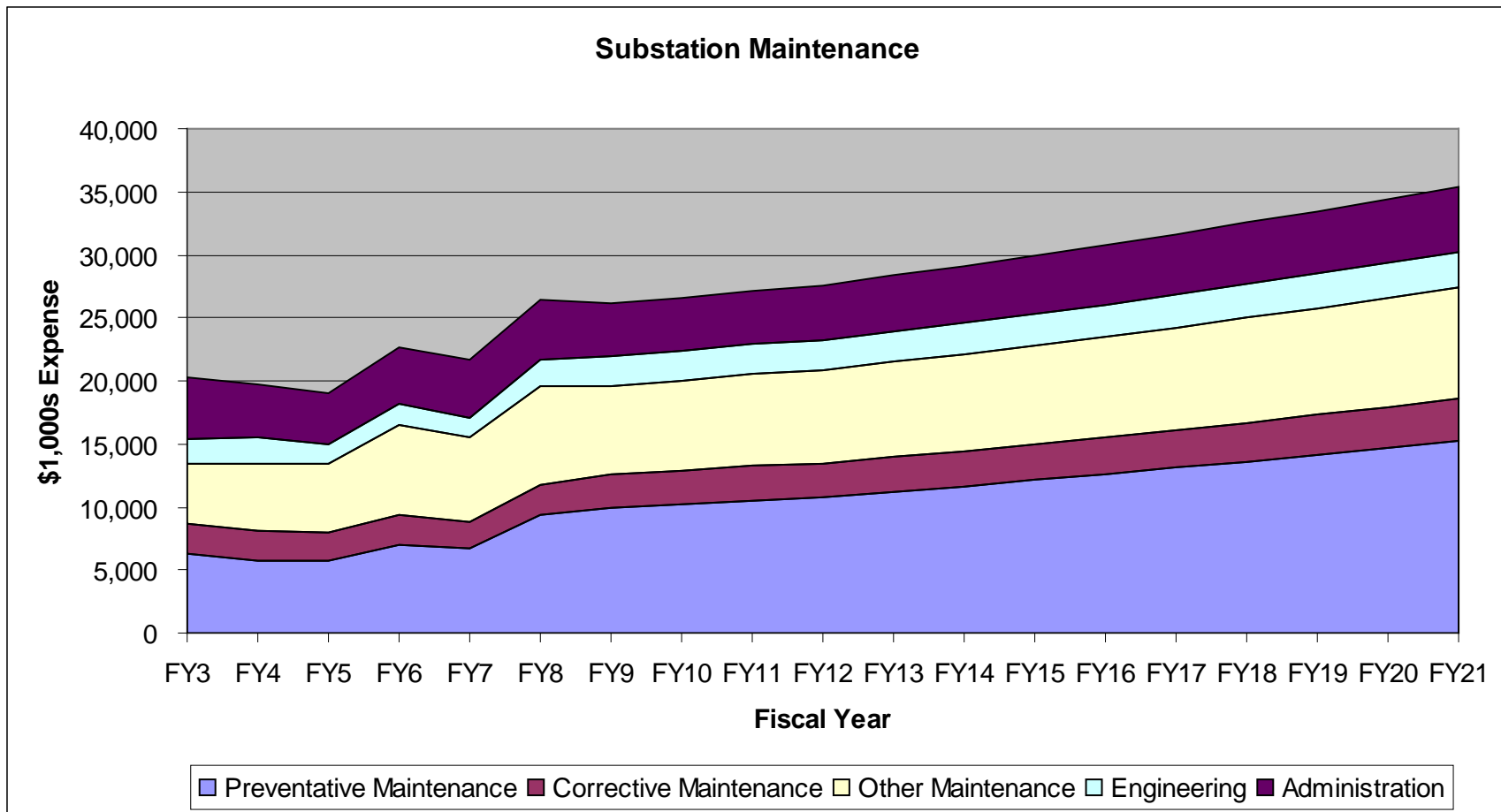
Substation Maintenance Expense Forecast (FY11 Millions \$)										
	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19	FY20	FY21
Preventative Maintenance	10.76	11.19	11.64	12.10	12.59	13.09	13.61	14.16	14.72	15.31
Corrective Maintenance	2.71	2.77	2.82	2.88	2.94	3.00	3.06	3.12	3.18	3.24
Other Maintenance	7.38	7.52	7.67	7.83	7.98	8.14	8.31	8.47	8.64	8.81
Engineering	2.37	2.42	2.47	2.52	2.57	2.62	2.67	2.72	2.78	2.83
Administration	4.38	4.46	4.55	4.64	4.74	4.83	4.93	5.03	5.13	5.23
Total Subs Expense	\$ 27.59	\$ 28.36	\$ 29.15	\$ 29.97	\$ 30.81	\$ 31.68	\$ 32.57	\$ 33.50	\$ 34.45	\$ 35.43
Assumptions:										
Based on historical trends FY 2003 through FY 2009										
\$ are in real terms, FY 2011										
Preventative maintenance growing at 4% per year to reflect equipment additions to system (i.e. growth, expansion)										
Expense is not adjusted to reflect impact of capital replacement program for these assets										
Other categories increase constant 2% based on history.										
No change in current maintenance practices										
Historical cost data adjusted for inflation, underlying trends in real \$\$										

Forecast Maintenance Costs

Capital investments will continue to offset increases in maintenance costs but the current forecasted rates of investment are not expected to result in a net decrease in substation maintenance costs. Variations in the offset depend on several major factors:

1. The rate of system expansion for which the full impact of the maintenance cost for new equipment will not be seen for several years. Following the initial investment (equipment is installed) the first major maintenance services may not be conducted for a period of 2 – 7 years depending on the equipment type.
2. The cost of procuring and warehousing (BPA or contracted warehousing) spare parts for maintenance and repair.
3. The cost and skill levels of labor resources (in house and contracted services).
4. A reduction in the number of units (substation equipment) that require maintenance, or simplification/optimization of the existing maintenance procedures. These are further clarified below:
 - The sale of delivery facilities and other changes in facility ownership can reduce the number of pieces of equipment BPA has to maintain. The potential gains are small due to slowed sales of delivery facilities and fewer remaining facilities eligible under this policy.
 - Changes in equipment technology that require less maintenance by design. Historically this has led to more frequent replacements due to shorter life cycles and sometimes increased costs in replacement parts by eliminating the ability to replace lower cost subcomponents vs. higher cost component systems.
 - Capital investments in newer technology, not only the high voltage equipment itself, but also monitoring equipment holds significant potential for implementing RCM principles. Reliability Centered Maintenance is heavily dependent on equipment performance factors such as failure trending at both the unit and subcomponent level particularly for power circuit breakers. With today's technology smart relays and similar data acquisition systems will be employed to help trend and project where maintenance is most needed based on the duty severity a piece of equipment is subjected to.

AC Substation – Momentum Maintenance Costs



Executive Summary

What equipment is covered?

Strategic environment & drivers

Strategies

Process improvements

Equipment Strategies

- Power transformers and reactors
- Switchgear
- Shunt capacitors
- Instrument transformers and surge arresters
- Station auxiliary
- Substation bus & structures

What will it cost?

 **Program Accomplishments FY10 & FY11**

FY10 Program Accomplishments

FY10 Program	Work Planned	Work Accomplished	Explanation for Variance
<p>0004454 Circuit Breakers and Switch Gear</p> <ul style="list-style-type: none"> •Circuit Breakers •Circuit Switchers •Disconnect Switches 	<ul style="list-style-type: none"> ▪Design on 22 pieces of switchgear ▪Fault Duty Switchgear ▪Maintenance Replacements <p>Emergency Replacements:</p> <ul style="list-style-type: none"> ▪ Walla Walla disconnect switch ▪ Covington 500kV disconnect switch 	<ul style="list-style-type: none"> - 22 designs complete -1 breaker installed - 5 disconnect switches - 7 disconnect switch projects completed that were started in FY09 or before. - 6 fault duty circuit breakers -3 fault duty disconnect switches - All emergency switchgear replacements complete. 	<ul style="list-style-type: none"> ▪Kitsap Sub replace 1 breaker moved to FY11 due to combining work with other onsite projects. ▪Kitsap Bus Tie breaker moved to FY11 due to material issues. ▪Ashe sub replace two 230KV PCB & two 500KV CS moved to FY12 due to material delays. ▪Ross fog test replace breaker delayed to FY11 due to emergency work priorities. ▪Ross EHV lab delayed to FY11 due to emergency work priorities. ▪Paul sub replace pantograph switches – 2 of 3 replaced, 1 delayed into FY12 due to outage constraint.

Subs AC Plan vs. Actuals, FY 10 (\$000s)

	FY 10 Plan	FY 10 Actuals
Circuit Brkr & Switch Gear	\$4,778	\$5,038
Transformers & Reactors	\$1,709	\$1,679
Shunt Capacitors	\$174	\$62
CVT/PT/CT & Arresters	\$734	\$802
Low Voltage Aux.	\$3,300	\$2,442
Bus & Structures	\$436	\$498
Total Capital Plan	\$11,131	\$10,521

FY10 Program Accomplishments

FY10 Program	Work Planned	Work Accomplished	Explanation for Variance
0005131 Transformers & Reactors <ul style="list-style-type: none"> •Power Transformers •Reactors •Fuses 	500kV Shunt Reactor - Malin 230kV Transformer – Langlois 8 Fuse Replacements Retire Transformers – Fidalgo & Lopez Island 7 Type U Bushing Replacements	230 KV transformer complete Fuse replacements complete: <ul style="list-style-type: none"> ▪ Burbank ▪ Scootney ▪ Cascade Locks 2 transformer retirements complete 1 Type U bushing complete	<ul style="list-style-type: none"> ▪ Pushed Malin shunt reactor to FY11 due to coordination with PGE on anchoring the reactor to the pad prior to dismantling. ▪ Dixie fuse replacement moved to FY11 due to outage. ▪ Hood River fuse replacement moved to FY12 due to outage. ▪ Sandpoint Fuse replacement moved to FY11 due to outage constraint. ▪ Scootney moved to FY12 due to outage and resources constraint ▪ Ringold moved to FY12

Subs AC Plan vs. Actuals, FY 10 (\$000s)

	FY 10 Plan	FY 10 Actuals
Circuit Brkr & Switch Gear	\$4,778	\$5,038
Transformers & Reactors	\$1,709	\$1,679
Shunt Capacitors	\$174	\$62
CVT/PT/CT & Arresters	\$734	\$802
Low Voltage Aux.	\$3,300	\$2,442
Bus & Structures	\$436	\$498
Total Capital Plan	\$11,131	\$10,521

FY10 Program Accomplishments

FY10 Program	Work Planned	Work Accomplished	Explanation for Variance
<p>0005140 Instrument Transformers and Arresters</p> <ul style="list-style-type: none"> •VT/CVT •CT •Arresters 	<p>Arrester replacements – 9 sites</p> <ul style="list-style-type: none"> ▪ Sandpoint ▪ LaClede ▪ Kalispell ▪ Goshen ▪ Libby ▪ Redmond ▪ Sickler ▪ St Johns ▪ Columbia <p>▪VT replacement – 1 site</p>	<p>Projects Arrester projects completed -</p> <ul style="list-style-type: none"> ▪ Kalispell ▪ Columbia ▪ Sandpoint ▪ LaClede ▪ Sickler (design completed, construction in FY11) <ul style="list-style-type: none"> ▪ 11 Emergency VT replacements – 4 complete ▪ 9 Emergency CT replacements – 4 complete ▪ 1 Emergency Arrester replacements - complete 	<p>Goshen moved to FY12 due to outage availability</p> <p>Libby moved to FY12 due to design issues.</p> <p>St Johns moved to FY12 due to outage availability.</p> <p>Redmond moved to FY11 due to material delay.</p>

Subs AC Plan vs. Actuals, FY 10 (\$000s)

	FY 10 Plan	FY 10 Actuals
Circuit Brkr & Switch Gear	\$4,778	\$5,038
Transformers & Reactors	\$1,709	\$1,679
Shunt Capacitors	\$174	\$62
CVT/PT/CT & Arresters	\$734	\$802
Low Voltage Aux.	\$3,300	\$2,442
Bus & Structures	\$436	\$498
Total Capital Plan	\$11,131	\$10,521

FY10 Program Accomplishments

FY10 Program	Work Planned	Work Accomplished	Explanation for Variance
0005517 Shunt Capacitors • Shunt Capacitors	Add surge arresters to fuseless shunt capacitor banks - 7 sites <ul style="list-style-type: none"> ▪ Addy ▪ Alvey ▪ Ashe ▪ Redmond ▪ Fairmount ▪ La Grande ▪ Santiam 	<ul style="list-style-type: none"> ▪ Design complete in FY10 for 4 out of 7 sites. (Fairmount, La Grande, and Santiam did not spend any dollars in FY10)	All seven sites moved to FY11 or beyond due to outage issues.

Subs AC Plan vs. Actuals, FY 10 (\$000s)

	FY 10 Plan	FY 10 Actuals
Circuit Brkr & Switch Gear	\$4,778	\$5,038
Transformers & Reactors	\$1,709	\$1,679
Shunt Capacitors	\$174	\$62
CVT/PT/CT & Arresters	\$734	\$802
Low Voltage Aux.	\$3,300	\$2,442
Bus & Structures	\$436	\$498
Total Capital Plan	\$11,131	\$10,521

FY10 Program Accomplishments

FY10 Program	Work Planned	Work Accomplished	Explanation for Variance
0005679 Low Voltage Aux. <ul style="list-style-type: none"> •Batteries & Chargers •SS Transformers •SS Cabling •Engine Generators •Grounding 	FY09 Batteries - 7 FY10 Batteries – 12 FY09 SS Replace – 11 Transfer Switch - Tillamook	Completed 4 FY09 batteries Completed batter replacements: <ul style="list-style-type: none"> ▪ Norway ▪ Walton ▪ Wren Tillamook transfer switch completed EMERGENCY <ul style="list-style-type: none"> ▪ Batteries 10 ▪ Chargers 5 ▪ Station Service 2 ▪ SS XFMRs 3 ▪ Cable Replacements 1 	FY10 Steilacoom and Badger Canyon moved to FY11 due to construction resource availability. Ellensburg moved to FY12 due to scope change Drain install SS equip. moved to FY11 due to material delay. Santiam replace. Bank #4 control cable moved to FY13 to save \$ & resources. St Johns 115KV SS PVTS delayed to FY13 due to design work Keeler SS upgrade moved to FY11 due to resource availability Lookout Point replace steel Bus & SS XFMRs delayed to FY13 due to construction resources. Ovando battery replacement moved to FY12 due to construction resource availability.

Subs AC Plan vs. Actuals, FY 10 (\$000s)

	FY 10 Plan	FY 10 Actuals
Circuit Brkr & Switch Gear	\$4,778	\$5,038
Transformers & Reactors	\$1,709	\$1,679
Shunt Capacitors	\$174	\$62
CVT/PT/CT & Arresters	\$734	\$802
Low Voltage Aux.	\$3,300	\$2,442
Bus & Structures	\$436	\$498
Total Capital Plan	\$11,131	\$10,521

FY10 Program Accomplishments

FY10 Program	Work Planned	Work Accomplished	Explanation for Variance
0005680 Bus & Structures <ul style="list-style-type: none"> •Bus •Bus Supports •Dead-end Towers •Lightning Masts •Foundations •Insulators •Engine Generator Fuel System & Housing 	Rigid Bus Riser Seismic Hardening – 8 sites <ul style="list-style-type: none"> ▪ Raver #1& #4 ▪ Schultz ▪ Allston ▪ South Tacoma ▪ Echo Lake ▪ Grizzly Bus Pedestal Replacement – Ashe Rock Creek Bus Phasing Corrections	Projects completed in FY10 <ul style="list-style-type: none"> ▪ Echo Lake ▪ Grizzly ▪ Raver #1 & #4 ▪ Schultz ▪ Allston ▪ South Tacoma Emergency Bus Riser Replacements – 3 sites	Ashe completed on 5/13/11 due to loss of outage. Original planned complete date was 9/15/10. Rock Creek Bus Phasing corrections schedule to complete 3/2011 but completed late due to loss of outage.

Subs AC Plan vs. Actuals, FY 10 (\$000s)

	FY 10 Plan	FY 10 Actuals
Circuit Brkr & Switch Gear	\$4,778	\$5,038
Transformers & Reactors	\$1,709	\$1,679
Shunt Capacitors	\$174	\$62
CVT/PT/CT & Arresters	\$734	\$802
Low Voltage Aux.	\$3,300	\$2,442
Bus & Structures	\$436	\$498
Total Capital Plan	\$11,131	\$10,521

FY11 Program Accomplishments

FY11 Program	Work Planned	Work Accomplished	Explanation for Variance
<p>0004454 Circuit Breakers and Switch Gear</p> <ul style="list-style-type: none"> •Circuit Breakers •Circuit Switchers •Disconnect Switches 	<ul style="list-style-type: none"> ▪Design on 20 pieces of switchgear ▪Fault Duty Switchgear ▪Maintenance Replacements <p>Emergency Replacements:</p> <ul style="list-style-type: none"> ▪ McNary - multiple ▪ Satsop ▪ Hanford ▪ Troy 	<ul style="list-style-type: none"> - All design complete - FY10 breakers complete: <ul style="list-style-type: none"> ▪ Kitsap breakers ▪ Langlois & Toledo replacements complete. ▪ Cardwell ▪ Drain ▪ Fairview ▪ Hood River <p>All emergency switchgear replacements complete.</p>	<ul style="list-style-type: none"> ▪Ross fog test replace breaker delayed again to FY12 due to emergency work priorities. ▪Ross EHV lab delayed again to FY12 due to emergency work priorities. ▪Ross disconnect switch moved to FY12 due to outage constraints. ▪Tahkenitch delayed to FY12 due to construction. ▪Libby & Hatwai delayed to FY13 due to construction resource availability.

Subs AC Plan vs. Actuals, FY11 (\$000s)

	FY 11 Plan	FY 11 Actuals
Circuit Brkr & Switch Gear	\$6,489	\$6,123
Transformers & Reactors	\$837	\$633
Shunt Capacitors	\$295	\$496
CVT/PT/CT & Arresters	\$1,285	959
Low Voltage Aux.	\$3,014	\$3,893
Bus & Structures	\$384	\$266
Total Capital Plan	\$12,304	\$12,370

FY11 Program Accomplishments

FY11 Program	Work Planned	Work Accomplished	Explanation for Variance
0005131 Transformers & Reactors <ul style="list-style-type: none"> •Power Transformers •Reactors •Fuses 	Fuse Replacements (FY10) Type U Bushing Replacements (FY10) GIC Transformer Monitors (construction in FY12): <ul style="list-style-type: none"> ▪ Bell ▪ Sacajawea ▪ Tillamook ▪ Vantage 	Malin Shunt Reactor complete FY10 fuse replacements: <ul style="list-style-type: none"> ▪ Ringold ▪ Sandpoint ▪ Dixie U Bushing replacements (FY10): <ul style="list-style-type: none"> ▪ Addy ▪ Allston ▪ Keeler ▪ McNary ▪ Pasco ▪ Port Angeles GIC Transformer monitors completed design 3 of 4 2 Emergency Transformers (spare) 500kV & 230KV	Not all Type U bushing replacements complete due to outage constraints Not all fuse replacements completed Did not complete design on one GIC Transformer Monitor

Subs AC Plan vs. Actuals, FY11 (\$000s)

	FY 11 Plan	FY 11 Actuals
Circuit Brkr & Switch Gear	\$6,489	\$6,123
Transformers & Reactors	\$837	\$633
Shunt Capacitors	\$295	\$496
CVT/PT/CT & Arresters	\$1,285	959
Low Voltage Aux.	\$3,014	\$3,893
Bus & Structures	\$384	\$266
Total Capital Plan	\$12,304	\$12,370

FY11 Program Accomplishments

FY11 Program	Work Planned	Work Accomplished	Explanation for Variance
0005140 Instrument Transformers and Arresters •VT/CVT •CT •Arresters	Arrester replacements <ul style="list-style-type: none"> ▪ Addy ▪ Keeler ▪ Ostrander ▪ Trentwood design Rod Gap replacement – 1 site CT retirement – Keeler PT replacement – 1 site	Arresters complete <ul style="list-style-type: none"> ▪ Redmond July 2011 (from FY10) ▪ Addy ▪ Keeler ▪ Ostrander CT retirement at Keeler complete Also complete: <ul style="list-style-type: none"> ▪ 10 Emergency VT replacements ▪ 8 Emergency CT replacements ▪ Emergency Arrester replacement – Shelton 	Arrester replacements not completed and pushed into FY12.

Subs AC Plan vs. Actuals, FY11 (\$000s)

	FY 11 Plan	FY 11 Actuals
Circuit Brkr & Switch Gear	\$6,489	\$6,123
Transformers & Reactors	\$837	\$633
Shunt Capacitors	\$295	\$496
CVT/PT/CT & Arresters	\$1,285	959
Low Voltage Aux.	\$3,014	\$3,893
Bus & Structures	\$384	\$266
Total Capital Plan	\$12,304	\$12,370

FY11 Program Accomplishments

FY11 Program	Work Planned	Work Accomplished	Explanation for Variance
<p>0005517 Shunt Capacitors</p> <ul style="list-style-type: none"> • Shunt Capacitors 	<ul style="list-style-type: none"> ▪ Add surge arresters to fuseless shunt capacitor banks - 7 sites ▪ Addy ▪ Alvey ▪ Ashe ▪ Redmond ▪ Fairmount ▪ La Grande ▪ Santiam 	<p>Construction complete at 5 sites in FY11</p> <ul style="list-style-type: none"> ▪ La Grande complete ▪ Fairmount complete ▪ Redmond complete ▪ Ashe complete ▪ Alvey complete 	<p>Ashe overspent by \$50K and Alvey over spent by \$80k.</p> <p>Santiam moved into FY12 due to outage availability.</p> <p>Addy moved to FY12 due to outage availability.</p>

Subs AC Plan vs. Actuals, FY11 (\$000s)

	FY 11 Plan	FY 11 Actuals
Circuit Brkr & Switch Gear	\$6,489	\$6,123
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Shunt Capacitors	\$295	\$496
CVT/PT/CT & Arresters	\$1,285	959
Low Voltage Aux.	\$3,014	\$3,893
Bus & Structures	\$384	\$266
Total Capital Plan	\$12,304	\$12,370

FY11 Program Accomplishments

FY11 Program	Work Planned	Work Accomplished	Explanation for Variance
0005679 Low Voltage Aux. <ul style="list-style-type: none"> •Batteries & Chargers •SS Transformers •SS Cabling •Engine Generators •Grounding 	FY09 Batteries – 3	F09 battery completed:	Franklin battery replacement moved to FY12 due to design change. Madison battery replacement moved to FY12 due to material issues. Keeler SS moved to FY12 due to construction issues. Salem replace/upgrade SS moved to FY12.
	FY10 Batteries – 9	<ul style="list-style-type: none"> ▪ Aberdeen ▪ Steilacoom Completed 8 FY10 batteries, In Progress 1	
	FY09 SS Replace – 10	Completed 5 FY09 SS replace., In Progress 5 2 Cable Replacements complete: <ul style="list-style-type: none"> ▪ Rockdale Radio Station ▪ Lane 	
	Cable Replacement – 1	EMERGENCY <ul style="list-style-type: none"> ▪ Batteries 8 ▪ Station Service 2 ▪ SS XFMRs 1 	

Subs AC Plan vs. Actuals, FY11 (\$000s)

	FY 11 Plan	FY 11 Actuals
Circuit Brkr & Switch Gear	\$6,489	\$6,123
Transformers & Reactors	\$837	\$633
Shunt Capacitors	\$295	\$496
CVT/PT/CT & Arresters	\$1,285	959
Low Voltage Aux.	\$3,014	\$3,893
Bus & Structures	\$384	\$266
Total Capital Plan	\$12,304	\$12,370

FY11 Program Accomplishments

FY11 Program	Work Planned	Work Accomplished	Explanation for Variance
0005680 Bus & Structures <ul style="list-style-type: none"> • Bus • Bus Supports • Dead-end Towers • Lightning Masts • Foundations • Insulators • Engine Generator Fuel System & Housing 	Rigid Bus Riser Seismic Hardening – 2 sites <ul style="list-style-type: none"> ▪ Ostrander ▪ Troutdale Bus Pedestal Replacement – 2 sites <ul style="list-style-type: none"> ▪ Monroe ▪ Ashe 	Completed in FY11 <ul style="list-style-type: none"> ▪ Ostrander ▪ Troutdale <ul style="list-style-type: none"> ▪ Monroe Bus Pedestal Replacement completed in FY11 <ul style="list-style-type: none"> ▪ Rock Creek Bus Phasing Corrections completed in May 2011 <ul style="list-style-type: none"> ▪ Emergency Bus Pedestal Replacement 	No variance

Subs AC Plan vs. Actuals, FY11 (\$000s)

	FY 11 Plan	FY 11 Actuals
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Total Capital Plan	\$12,304	\$12,370