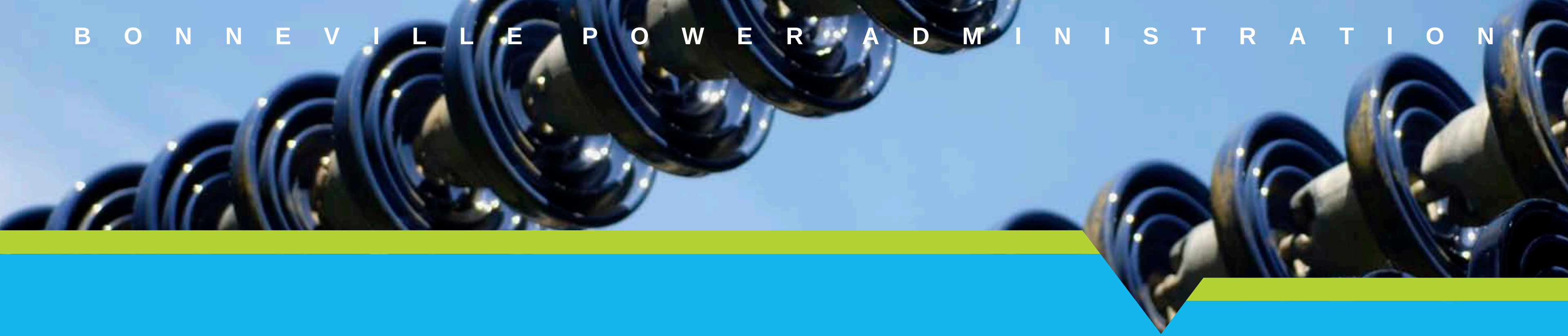


# System Protection and Control

## Sustain Program
## Asset Management Strategy

Curtis Michael, Program Manager

March 2012

# Executive Summary

## System Protection and Control (SPC) Sustain Program

### Assets Covered

The SPC Sustain Program covers replacement and upgrade of the following equipment:

**Protective Relaying** – Provides fast isolation of faulted or failed power system components to provide system stability and prevent further damage

**Sequential Events Recorders** – Maintains an historical record of all substation equipment operations and alarms; interfaces with station SCADA to provide remote monitoring capability to the control centers

**Fault Recorders** – Provides fault data for troubleshooting and evaluating system operation and health

**Revenue and Interchange Metering** – Provides accurate meter data for billing and scheduling of energy exchange

**Control and Indication Equipment** – Provides ability to monitor and control the power system both locally and remotely

# Executive Summary (Cont)

- Strategic Drivers for the SPC Sustain Program (All Asset Categories)
  - Lack of OEM support for most SPC equipment due to advanced age
  - Poor Health condition assessment for older SPC equipment
  - Decreasing skill set to maintain older equipment as SPC employees retire
  - Increased corrective maintenance workload to maintain older equipment in poor health

- Protective Relaying
  - Strategic Goal
    - Replace all non-microprocessor protective relays with microprocessor protective relays during the 10-year planning horizon (approximately 600 terminals)
  - Over the planning horizon we will achieve this by
    - Replacing 60 terminals of electronic protective relays per year with microprocessor protective relays

- DFR
  - Strategic Goal
    - Replace all non-BEN DFRs with BEN6000 DFRs (Approximately 10 units)
  - Over the planning horizon we will achieve this by
    - Replacing 2 DFR units per year until all units have been replaced, then managing the units on a 15-18 year lifecycle

# Executive Summary (Cont)

- SER
  - Strategic Goal
    - Actively coordinate with the PSC Sustain Program to replace all Beta SERs with the current SER/SCADA standard (approximately 83 units)
  - Over the planning horizon we will achieve this by
    - Replacing 12-16 units per year, combined PSC Sustain and SPC Sustain Programs

- Revenue and Interchange Metering
  - Strategic Goal
    - Replace 50% of the at risk revenue and interchange meters (650 units to be replaced)
  - Over the planning horizon we will achieve this by
    - Replacing 65 units per year

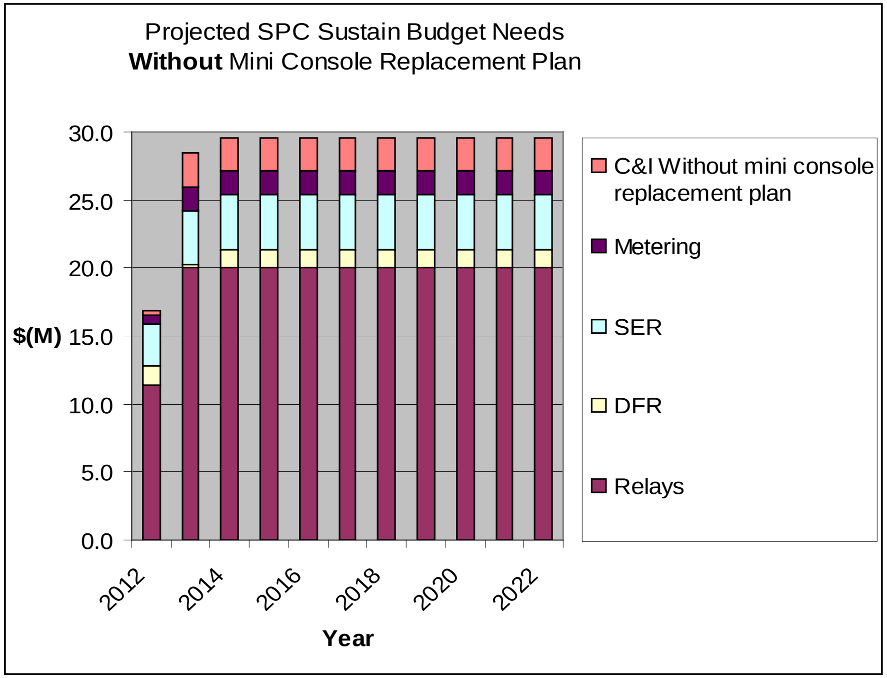
- Control & Indication
  - Strategic Goal
    - Develop a lower cost mini console replacement and begin replacing those units.
  - Over the planning horizon we will achieve this by
    - Working with the Data Systems Design Group to develop a new human interface standard that uses current technology, has a 1-3 rack foot print and can be implemented for <$500K

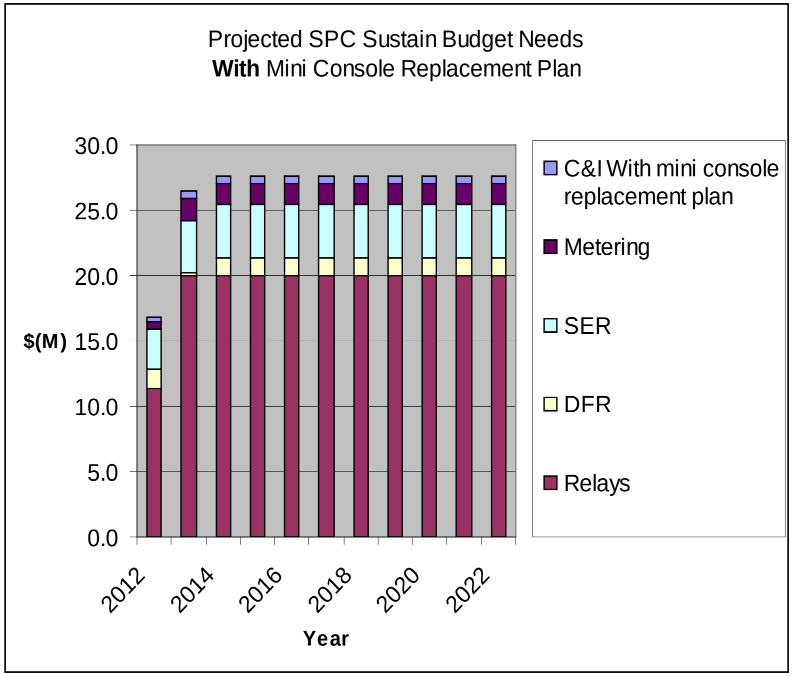
# Executive Summary (Cont)

## Projected Budget

| Year | Relays | DFR | SER | Metering | C&I |
|---|---|---|---|---|---|
| **2012** | $11.4M | $1.4M | $3.1M | $0.6M | $0.3M |
| **2013** | $20M | $0.2M | $4M | $1.7M | $2.5M/$0.5M* |
| **2014-2022** | $20M | $1.4M | $4M | $1.7M | $2.5M/$0.5M* |

* Projected savings with Mini Console Replacement Plan approximately $2M/yr for 10 years



# Executive Summary (Cont)

## Risks of underfunding

If the SPC Sustain program continues to be underfunded:

- Asset Condition will continue to deteriorate, while risk of equipment failure escalate
- Maintenance costs will increase as more corrective work is required
- Emergency capital replacements will become the norm and will disrupt planned work
- Reliability of the power system will be compromised

# Business Environment

- Characteristics of assets covered
  - Protective relays for all power system components
  - Sequential event recorders in substations
  - Revenue and interchange meters monitoring and recording energy exchange
  - Fault recorders in substations
  - Control and indication equipment in substations
- Customers and stakeholders served
  - Stakeholders of all BPA power system components require isolation of equipment during fault conditions to prevent equipment damage and protect personal safety
  - BPA operations and control center personnel require system control and monitoring to operate and maintain the power system
  - BPA internal billing and scheduling organizations and external customers require accurate meter data
  - Maintenance personnel use fault and event data to locate, troubleshoot and correct system failures
  - BPA external power and transmission customers require reliable power; SPC equipment contributes to that reliability
- Products and services
  - Fast isolation of faulted or failed power system components provides system stability and prevents further equipment damage
  - Ability to monitor and control the power system both locally and remotely
  - Accurate meter data for scheduling and billing of energy exchange
  - Fault data for troubleshooting and evaluating system operation and health
  - Remedial action schemes ensure greater system stability allowing more energy transfer across a given path

# Business Environment

- Strategic environment
  - Regulatory and legal standards
    - FERC, NERC and WECC regulation and standards are continually evolving; the trend is toward more understandable and specific standards that in turn may require modification of our relay setting and maintenance practices and require more detailed documentation of our work
    - Recently implemented relay setting standards have initiated many relay replacements
    - Forthcoming equipment and maintenance standards have potential to influence where certain equipment must be installed and how our equipment is maintained
    - There is always regulatory pressure to improve relay setting coordination and reduce relay misoperations
  - Complexity of protection schemes
    - Complexity of the power system being protected has direct impact on the magnitude of challenges the protection engineer faces when developing the protection scheme or relay settings
    - Past benchmarking efforts have shown that BPA's protection schemes are among the most complex in the industry
    - Factors that contribute to this complexity are generation integration, three terminal transmission lines, series capacitors, parallel lines, mutual inductance and single pole tripping of 3-phase circuit breakers
    - Also BPA uses RAS extensively and some RAS functions are being accomplished in the protective relays especially on the 500kV system
    - The high degree of flexibility in programming modern digital relays has lead to challenges in coordinating protection schemes that span across utility boundaries; each utility has developed their unique means of implementing a particular type of relay so compromises and adjustments must be made when coordinating with other utilities
  - Constraints resulting from expanding capital program - A much larger replacement program that will be required to retire 30 year old and older SPC equipment has potential to reach constraints in the entire construction process including estimating, design, outage planning, construction, testing & energization

# Business Environment

- Strategic environment (cont.)
  - Generation integration
    - Wind generation is frequently interconnected in the middle of a transmission line requiring complicated protection schemes
    - BPA is having difficulty getting data for accurate fault modeling of some new wind generation sites leading to low confidence in that aspect of our fault study model; as a result, some relay settings cannot be optimized to ensure the most effective protection scheme is employed. (this data is optimized for power flow studies rather than fault studies.)
  - Commodities
    - Many types of existing SPC equipment are no longer supported by the manufacturer and replacements parts are not available
    - Shorter life expectancy of new digital equipment will result in a faster tempo replacement program than we have seen with the electro-mechanical relays
  - Integrated Control System Strategy (ICSS)
    - Consultant led effort to coordinate the SPC, PSC and Control Center strategies to realize efficiencies through optimization of equipment upgrades.
  - Staffing constraints
    - Construction of expansion projects takes FTE resources from maintenance and replacement efforts
    - SPC inventory has many types of legacy and modern equipment requiring a huge knowledge base for engineers and craftsmen
    - Expertise to maintain, troubleshoot and repair obsolete equipment is held only by BPA personnel since manufacturer support not longer exists; most of these experts are either at or within 3 years of retirement age.
    - Hiring and training of new engineers and craftsmen to replace a large number of retiring personnel
    - Complexity of new equipment results in challenges training personnel to set, test, and maintain it

**What equipment and facilities are covered?**

What performance objectives, measures and targets should be set?

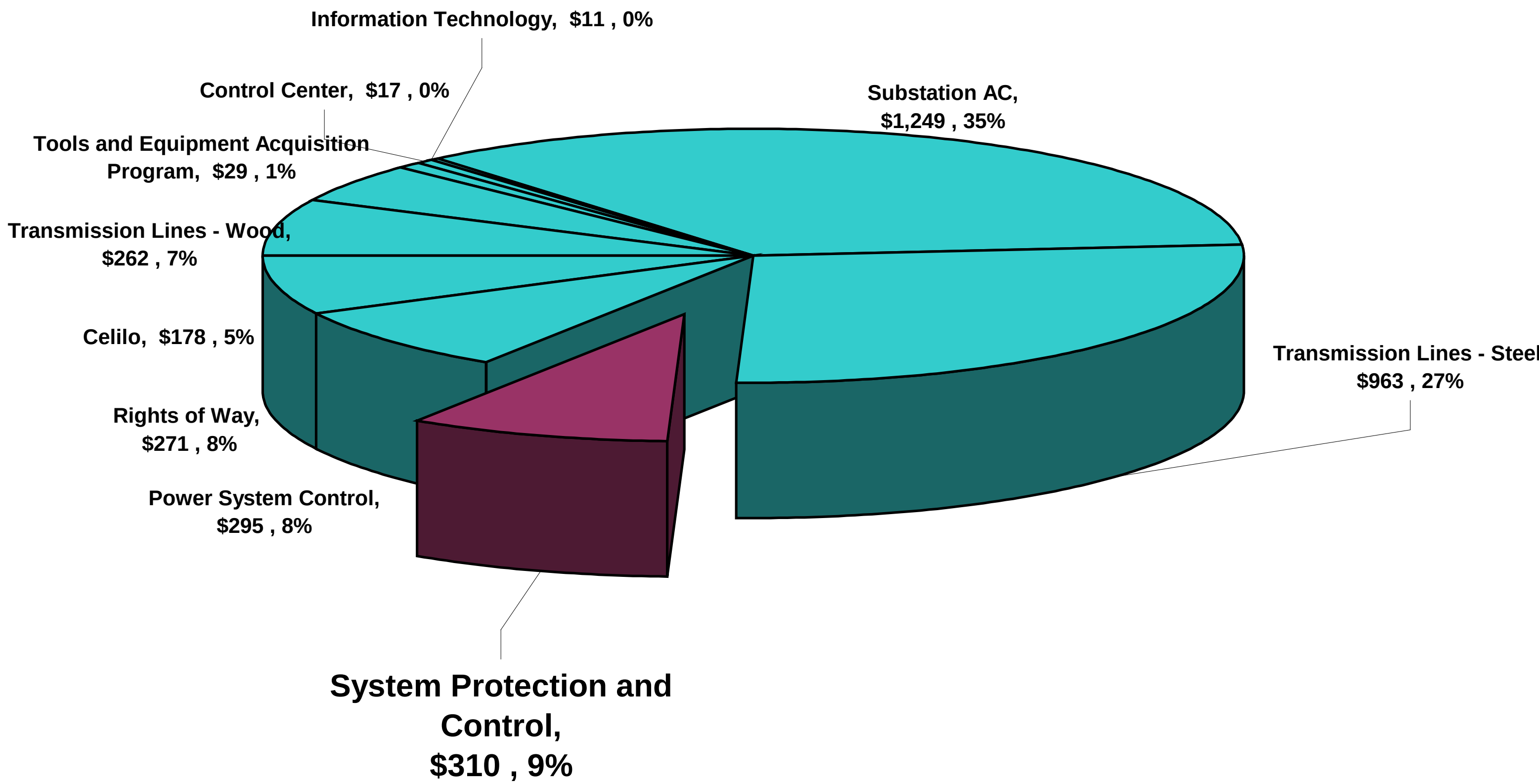
What is the health of the assets, and what risks must be managed?

What strategies should we undertake?

What will it cost?

# Transmission Book Value

**Transmission Sustain Programs**
**Historical Investment After Depreciation**
**as of Sept. 30, 2011**
(in millions)
**Total Book Value is $ 3,585 million**



# SPC Assets

- Identify assets
  - Power system protection, control and metering equipment is in every BPA substation and in many customer facilities interconnected to the BPA system.
  - These systems provide critical support to the primary circuit elements by preserving equipment integrity, maintaining overall reliability, gathering and storing operational data and ensuring public safety
  - Assets categories include:

    Protective Relays

    – Protective relays are of three different technology eras, electro-mechanical, electronic and microprocessor based
      - Electromechanical relays - installed up to 1983 with a 30 year life expectancy
      - Electronic relays - installed 1980 through 1995 with 15 to 20 year life expectancy
      - Digital relays - installed 1987 to present with 15 to 20 year life expectancy

    – Transmission lines, power transformers, circuit breakers, substation buses, reactor and capacitor banks are all protected by these relays from damage caused by power system faults and equipment failures

    – By quickly isolating power system faults, protective relays play a key role in maintaining the bulk electric system stability

    – Remedial action schemes (RAS) are special protection schemes included in this category; RAS equipment within the SPC program consists of input/output (I/O) relays for line loss logic and generation and load dropping, power rate relays, and logic controllers

    Sequential Events Recorders

    – SERs are located in 140 of the large or more significant BPA substations

    – The first SERs were installed in the mid 1980’s to replace rudimentary annunciator panels

    – SERs maintain a historical record of all equipment operations and alarms in a substation and interface with station SCADA to provide remote monitoring capability to the control centers

# SPC Assets

- Identify assets (cont.)
  - Asset categories (cont.)

    <u>Fault Recorders</u>
    - Digital fault recorders superseded the oscillograph in the mid 1980’s
    - There are 105 in the more significant substations across the BPA system
    - They record voltage and current waveforms during system faults; the data is used by SPC engineers to validate proper power system response to faults, troubleshoot equipment misoperation (internal and external to the BPA system) and improve relay setting coordination

    <u>Revenue and Interchange Meters</u>
    - Approximately 1600 revenue and interchange meters are in operation at BPA and customer owned facilities
    - Data from revenue meters is used by BPA’s billing organization to account for power entering and leaving the BPA power system
    - Interchange meters measure power entering or leaving the BPA balancing authority area
    - Some revenue meters and all interchange meters provide data for automatic generation control (AGC)

    <u>Control and Indication Equipment</u>
    - The SPC program has responsibility for a variety of substation control and indicating equipment
    - Control equipment includes auto sectionalizing, dead bus clearing, auto synchronizing schemes and synchronous control units (SCU)
    - Indicating equipment includes phasor measurement units (PMU), panel meters, control consoles, transformer temperature monitors, recording voltmeters, battery voltmeters, battery ground monitors, SCADA transducers, relay communication processors, and interconnecting wiring

# Asset Criticality

- Criticality of assets
  - Most SPC equipment protects and/or supports primary assets so their criticality is based on the criticality of the asset they support
  - Criticality of protective relays is tied directly to the transmission line or substation equipment being protected by the relay; in the case of RAS, criticality is based on the transmission corridor they protect
  - Protective relays and RAS also perform a system wide function of ensuring power system stability and therefore preventing cascading outages; in this regard protective relays and RAS take on a criticality related to overall power system stability
  - Fault recorders and sequential event recorders criticality is based on the criticality of the substation where they reside; adding to their criticality, they also play a key role when reconstructing disturbance related outages or system events; this information is used primarily by BPA but may also be required for use by external regulatory agencies
  - Revenue meters are BPA's cash register; their criticality is based on financial risk rather than operational or power system reliability risk
  - Criticality of revenue and interchange meters providing data to AGC is based on the criticality or capacity of the generation or interchange site they monitor; they also have a criticality component based on AGC's overall contribution to maintaining power system stability

What equipment and facilities are covered?

**What performance objectives, measures and targets should be set?**

What is the health of the assets, and what risks must be managed?

What strategies should we undertake?

What will it cost?

# Key Standards and Requirements

## SPC Equipment Health Condition

- **Performance Objective**: Relays and other critical SPC equipment are at low risk of failure or obsolescence
- **Measures**:
  - Standardization and frequency of condition assessment for SPC equipment
  - Percent of SPC equipment that are assessed to be in poor health condition based on maintainability and obsolescence
- **End-stage targets**:
  - Health condition of SPC equipment is assessed consistently with (1) condition-based standards, (2) standardized inspection protocols (including schedule), and (3) standardized risk assessment criteria
  - By the end of FY 2016, no more than 5 percent of total protective relays and no more than 20 percent of SERS are in poor health condition

# Key Standards and Requirements

## Protective Relay Reliability

- **Performance Objective**:  Protective relays clear power system faults sufficiently fast to prevent primary equipment damage or power system instability and ensure personnel and public safety
- **Measure**:  Number of relay misoperations reported in the Outage Analysis and Reporting System (OARS)
- **End-stage target**:
  - 0.5% or less of relay operations reported in OARS each year are a result of relay malfunction (not setting trouble) where the relay failed to operate for a fault inside of its zone of protection
  - 2.0% or less of relay operations reported in OARS each year are a result of relay setting trouble where the relay failed to operate for a fault inside of its zone of protection

## Protective Relay Security (assurance a relay will not trip inappropriately or “false trip”)

- **Performance Objective**:  When no fault is present and under normal operating conditions, relays should not initiate a trip as a result of component or equipment failure within the relay
- **Measure**:  Number of relay misoperations reported in the Outage Analysis and Reporting System (OARS)
- **End-stage target**:
  - 0.5% or less of relay operations reported in OARS each year are a result of relay malfunction (not setting trouble) where the relay operated for a fault outside of its zone of protection or operated when there was no fault on the system
  - 1.0% or less of relay operations reported in OARS each year are a result of relay setting trouble where the relay operated for a fault outside of its zone of protection or operated when there was no fault on the system

# Key Standards and Requirements

## Sequential Events Recorder Accuracy

- **Performance Objective:** All events that occur on monitored and in-service substation equipment are recorded and time stamped within the accuracy of the GPS clock
- **Measures:** Number of reported loss of synchronization alarms (Most SPC districts do not program SERs to automatically monitor and collect instances of SER loss of sync alarms)
- **End-stage Target:** SER is synchronized with the station GPS clock to facilitate coordination of SER data with data from other time synchronized substation data recording devices

## Sequential Events Recorder Availability/Reliability

- **Performance Objective:** Recorded SER data is immediately available to field and control center personnel in electronic form and hardcopy format at the substation for monitoring the operation and health of the power system and to analyze or troubleshoot system problems
- **Measures:** Number of reported SER trouble alarms (no system is presently in place to automatically monitor and collect instances of SER trouble alarms)
- **End-stage Target:** Chronologically continuous substation event data is recorded by the SER and is immediately available for use by operations and maintenance personnel locally and remotely where access exists

What equipment and facilities are covered?

What performance objectives, measures and targets should be set?

**What is the health of the assets, and what risks must be managed?**

What strategies should we undertake?

What will it cost?

# Current State of the Assets

## Protective Relays

Protective relays fit into 2 groups related to their technology characteristics

- Non microprocessor based
  - includes electro-mechanical (E/M) and electronic relays
  - by nature of their design these relays tend to drift out of calibration and therefore require more frequent maintenance (every 36 months)
  - With age wiring insulation becomes brittle potentially compromising their circuitry when the relays are handled for maintenance or repair; aging components also result in setting drift so in some instances these relays cannot be maintained within calibration limits
  - In most cases spare component parts are no longer available
  - BPA has traditionally assumed E/M relays to have a 30 year life expectancy; E/M relays on the system are 27 to 47 years old
  - Electronic relays have a shorter operating life of 15 to 20 years; BPA's electronic relays are 17 to 28 years old
  - Electronic relays employed on the BPA system are much more complex than the E/M relays; they require extensive training for field and technical services personnel to maintain, troubleshoot and repair them
  - One model of electronic relay employed at BPA is the INX5 bus differential relay; it has an added vulnerability of being employed as single layer protection; that means if one of these relays fails the substation bus is without protection and must be deenergized
  - Mfg support is no longer available for electronic relays or for many models of E/M relays

# Current State of the Assets

## Protective Relays (cont.)

- Microprocessor based (digital)
  - Digital relays do not drift out of calibration like E/M and electronic relays so maintenance intervals are extended (every 60 months)
  - The modern microprocessor based relays are intelligent electronic devices (IED) meaning they have the capability to communicate and share data with other substation equipment providing opportunity for better substation automation and implementation of Smart Grid technologies
  - Digital relays have fault and event recording capability providing significant advantage in substations that do not have a SER or DFR; this functionality becomes an invaluable resource when troubleshooting and resolving system disturbances and equipment trouble
  - Rapidly changing technology has resulted in component obsolescence often within 15 years
  - Protective relay models are commonly manufactured for only 5-7 years; hardware and software support may continue for an additional 5-7 years; once mfg support has ended the relays must be supported by BPA internal expertise until the equipment is replaced
  - When obsolete components such as the central processing unit (CPU) or mass memory storage fail, they cannot be replaced at the component or circuit board level necessitating a complete relay replacement
  - Digital relays require frequent firmware or operating system upgrades to correct errors found by users or the manufacturer; left uncorrected these software errors can result in a failure to trip or false tripping of a relay
  - BPA's oldest digital relays are 25 years old

# Current State of the Assets

Protective Relays (cont.)

- The electronic relay technology was applied primarily to protect 500kV transmission lines and 115-500kV substation buses
- E/M relays continued to be used in the most protection categories until the advent of digital relays in the late 1980's
- Of the 1295 non-micro processor based relays approximately 1160 are E/M, 135 are electronic line and bus differential relays

| Relay Terminals by Category and Type (Nov 2011) | | |
|---|---|---|
| **Relay Category** | **non-micro processor** | **micro processor** |
| Line, bus-tie, bus differential, breaker failure, reclosing: | | |
| 500kV | 308 | 516 |
| 57-345kV | 483 | 843 |
| <57kV | 201 | 31 |
| Shunt capacitors and reactors: | | |
| | 57 | 242 |
| Transformers: | | |
| <50MVA | 40 | 5 |
| >50MVA | 180 | 39 |
| Under frequency load shedding: | | |
| | 26 | 18 |
| | | |
| Total: | 1295 | 1694 |

# Current State of the Assets

## Protective Relays (cont.)

- Relay performance
  - Since April 1, 2008 BPA has been specifically tracking relay misoperations using the Outage Analysis and Reporting System (OARS); as of Dec 21,2011 there have been
    - 2897 recorded relay operations
    - 74 of those were classified as misoperations of the protective scheme
    - 16 were attributed to relay malfunction
      - This represents a 0.55% operation rate due to relay or relay component trouble
    - 58 were attributed to a relay setting problem of some sort
      - This represents a 2.0% operation rate due to relay setting trouble
    - The remaining 93 misoperations were communication system errors or other non-SPC related trouble
  - Relay trouble tracked in Asset Suite
    - When relay trouble requiring corrective action is found, SPC personnel create a corrective work order to capture labor and materials used to correct the problem; policy requires that a history brief in Asset Suite also be completed to record details of the problem and action taken
    - Corrective maintenance data is available for equipment categories as they are defined in Asset Suite; these categories do not go to the detail of equipment model so equipment model specific data is not available.
    - As a result trending and analysis of trouble specific to relay model or application is not possible
    - Cascade, BPA's new Asset Registry went live during the first half of calendar year 2011 and will provide better means of tracking and trending equipment health
    - This is typical of all equipment types in the SPC program

# Current State of the Assets

## Protective Relays (cont.)

Remedial Action Schemes

- RAS are special protection schemes within the protective relay category
- BPA has 7 wide area and 13 local area RAS ranging in age from 35 years to newly constructed
- In the older schemes, RAS I/O devices used for line loss logic (LLL) are simple electro-mechanical repeat relays that are still available from the manufacturer
- In the event of failure of these older I/O components, replacement parts are in stock in the BPA warehouse
- For RAS components under the umbrella of the SPC sustain program, the equipment is supported and/or replacement parts are readily available
- The DC RAS scheme is in process of a complete replacement funded via a capital upgrade project
- Other schemes require replacement of communication equipment and are being handled under the PSC sustain program

# Current State of the Assets

## Sequential Events Recorders

- With the advent of micro electronics in the late 1980's the SER's in use today became available and were installed in critical BPA substations replacing annunciator panels and early vintage event recorders
- The BETA 512 is the earliest model SER on operation on the BPA system
- The next generation used was the BETA 4100
- Today the standard equipment for new or replacement SER installations is a GE D20
- SER installation dates are not available in Asset Suite before 2006 so installation dates at specific locations are only available in hardcopy records at the various SPC district headquarters

| Model | Number in operation | Approximate period of installation |
|---|---|---|
| BETA 512 | 83 | 1987 to 1994 |
| BETA 4100 | 62 | 1994 to 2009 |
| BPA custom design | 3 | 2002 to 2005 |
| Misc | 5 | unknown |
| D20 | 4 | 2008 to present |
| Total: | 157 | |

# Current State of the Assets

<u>Sequential Events Recorders (cont.)</u>

- BETA 512
  - The BETA 512 is no longer supported by the manufacturer so there are no new spare parts available
  - BPA knows of and uses one electronics shop able to repair component parts for the BETA 512
  - Since no new parts are available for these units a SPC policy has been established that requires replacement of a BETA 512 SER when a substation expansion project requires expansion of the SER unit
  - The oldest of these units are 22 years old and have reached their life expectancy
- BETA 4100
  - The BETA 4100 is no longer supported by the manufacturer so there are no new spare parts available
  - BPA knows of and uses one electronics shop able to repair component parts for the BETA 4100
  - Since no new parts are available for these units a SPC policy has been established that requires replacement of a BETA 4100 SER when a substation expansion project requires expansion of the SER unit
  - The oldest of these units are 15 years old

# Current State of the Assets

## Sequential Events Recorders (cont.)

- BPA custom designed SER's
  - 1998 through 2004 BPA installed 6 SER's that were BPA custom designs with the intent to move toward substation automation
  - These designs of SER were installed at Pearl, Substation X, Red Mountain, Wautoma, Napavine substations and Celilo converter station
  - All 6 designs were similar but each one unique, these SER's have proven unreliable, maintenance intensive, and some critical components that are prone to failure are already obsolete and unavailable
  - In addition the original designers are no longer with BPA, documentation is incomplete and present maintenance personnel do not have the required knowledge to troubleshoot and repair problems
  - The SER at Pearl, Napavine and Red Mountain have been replaced; the replacement process for Wautoma and Sub X is planned to begin in FY2012
  - These units have been particularly difficult for field personnel to maintain and troubleshoot problems
  - Because these systems are so unique and virtually no technical documentation exists, field and technical services personnel have spent an inordinate amount of time simply working to understand the basics of how these systems operate as they troubleshoot and correct the frequent failures
- D20 – current BPA SER standard
  - The D20 has the capability of accomplishing both SER and SCADA functions
  - BPA is now using the D20's capability to combine SER and SCADA function into one unit thus gaining efficiency in construction and maintenance
  - The D20 also makes a large stride forward in BPA's ability to share information between the various substation equipment providing opportunity for improved substation automation and implementation of Smart Grid technologies

# Current State of the Assets

Digital Fault Recorders

- The first DFR used widely on the BPA system is the Rochester TR1620
- The BEN 5000 was the next standard DFR
- Today the next generation of BEN DFR, the BEN 6000, is being installed
- The Rochester TR1620 DFR is no longer supported by the manufacturer so spare parts are not available
- Some key components on the Rochester’s are failing such as the mass memory drive; the only replacements parts are those cannibalized from retired units
- An aggressive replacement program is in place to retire the remaining Rochester DFR’s by the end of FY2017
- The BEN 5000 is well supported by the manufacturer; SPC expects this equipment will meet system needs and not require replacement until approximately 2020

# Current State of the Assets

Revenue and Interchange Meters

- BPA has approximately 1600 meters at 1340 different locations
- The JEM 1 is the oldest meter in use at BPA
  - First installed at BPA in 1981, there are approximately 1260 in operation
  - This is an electronic analog meter
  - The technology is no longer supported by the manufacturer however they are a robust meter and the component circuit cards can be repaired
  - The JEM 1 meter requires an associated recorder to record and total the meter pulses and to communicate with the MV90 billing system; this meter configuration is unique to BPA resulting from the continued use of the JEM 1 meters
  - Approximately 300 of these are AGC or interchange meters equipped with EXJ registers used to collect and transmit telemetry data to the control centers
  - Replacement EXJ registers are available at present but the cost is rising significantly indicative of impending obsolescence
- The JEM 10 is the next meter standard used by BPA
  - This is a digital meter
  - JEM 10 first installed in the mid 1990’s
  - 92 of them presently in use
- The JEMSTAR is BPA’s standard revenue meter today
  - It is a digital meter
  - 238 in use on the BPA system

# Current State of the Assets

## Control and Indication

- The 4 general types of control equipment are listed below with the number on the BPA system
  - Dead bus clearing schemes – 64
  - Auto sychronizing schemes – 18
  - Auto sectionalizing schemes – 10
  - Synchronous control units (SCU) – 30
- There are several types of indicating equipment including
  - Phasor measurement units (PMU)
  - Relay communication processors
  - Panel meters
  - Control consoles
  - Recording volt meters
  - SCADA transducers
  - Battery volt meters and ground detectors
- The SCU's and some "mini" control consoles are obsolete and require replacement at this time
- The analog panel meters are obsolete; they are being replaced in conjunction with other capital work such as relay replacements or using a corrective work order when a failure occurs
- Additional condition assessment is required on the control and indication equipment in order to develop a thorough 10 year asset strategy

# Current State of the Assets

| Overall Component Health Demographics | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Maintainability | | | Obsolescence | | | Asset |
| Major SPC Component | Good | Fair | Poor | Good | Fair | Poor | Health |
| **Electro-Mechanical Relays** | | | | | | | |
| 500kV | | | | | | | Impaired |
| 230-345kV | | | | | | | Impaired |
| 69-169kV | | | | | | | Impaired |
| <69kV | | | | | | | Impaired |
| Transformer & Reactive | | | | | | | Impaired |
| Special Protection & Control Schemes (RAS) | | | | | | | Fine |
| **Electronic Relays** | | | | | | | |
| 500kV | | | | | | | Poor |
| 230-345kV | | | | | | | Poor |
| 69-169kV | | | | | | | Poor |
| <69kV | | | | | | | Poor |
| Transformer & Reactive | | | | | | | Poor |
| Special Protection & Control Schemes (RAS) | | | | | | | Poor |

# Current State of the Assets

| Overall Component Health Demographics | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Maintainability | | | Obsolescence | | | Asset |
| Major SPC Component | Good | Fair | Poor | Good | Fair | Poor | Health |
| **Digital Relays** | | | | | | | |
| 500kV | | | | | | | Fine |
| 230-345kV | | | | | | | Fine |
| 69-169kV | | | | | | | Fine |
| <69kV | | | | | | | Fine |
| Transformer & Reactive | | | | | | | Fine |
| Special Protection & Control Schemes (RAS) | | | | | | | Good |
| **SERs** | | | | | | | |
| BETA 512 | | | | | | | Poor |
| BETA 4100 | | | | | | | Impaired |
| D20 | | | | | | | Good |
| **DFRs** | | | | | | | |
| Rochester | | | | | | | Poor |
| BEN | | | | | | | Good |
| **Revenue Meters** | | | | | | | |
| Electronic | | | | | | | Fair |
| Digital | | | | | | | Good |
| Remote Metering System | | | | | | | Impaired |

# Current State of the Assets

Planned Outages

- The need for and duration of planned outages for maintenance or replacement of SPC equipment varies widely based on the type and complexity of the equipment
- Protective relay maintenance typically requires only a short outage on the protected equipment for trip checks to verify proper operation of the trip circuit from the relay to the associated isolation device
- Replacement of protective relays normally requires a planned outage of the protected equipment; the outage duration increases with the complexity of the protection scheme; where substations have a bus-tie breaker, outages for line relay replacements can be minimized or eliminated
- Planned outage durations for SPC equipment replacement are not recorded in a way that they are easily researched to provide typical values for outages associated with relay replacements
- Replacement of SERs, DFRs, and meters typically does not require outages of any primary power system equipment
- As the capital replacement program ramps up based on the requirements of the several asset program strategies, the ability to obtain outages for construction (based on system operational constraints) is a probable constraint that will limit the rate of capital replacement

# Current State of the Assets

## Maintenance Cost History

- Preventive and corrective maintenance costs are tracked in Asset Suite via work order for all SPC equipment
- The way equipment data is organized in Asset Suite, considerable effort may be required to sort data to determine typical maintenance costs per equipment type; for example electromechanical and electronic relays are grouped together as non-microprocessor based relays so maintenance cost data for either group would have to be sorted manually; one goal of the transmission asset system (TAS) project is to provide more detailed maintenance cost data
- PM work on protective relays is specific to a relay terminal that has multiple relays in it; therefore cost specific to a given relay model is not available

## Replacement Cost History

SPC equipment replacement costs shown below and used in program funding development are based on:

- Typical direct costs from like projects provided by project managers most familiar with these projects
- Reflect 2009 dollars
- Assumes BPA labor is used for the entire project – design through construction and T&E

| Equipment Type | Typical Replacement Cost per terminal (in $1000s) |
|---|---|
| 500kV Line Relay w/ TT | $500 |
| 115-230kV Line Relay w/o TT | $150 |
| 500kV Bus Differential Relay | $325 |
| DFR | $295 |
| SER | $250 |
| Revenue Meter | $27 |

# Current State of the Assets

## Maintenance Backlog

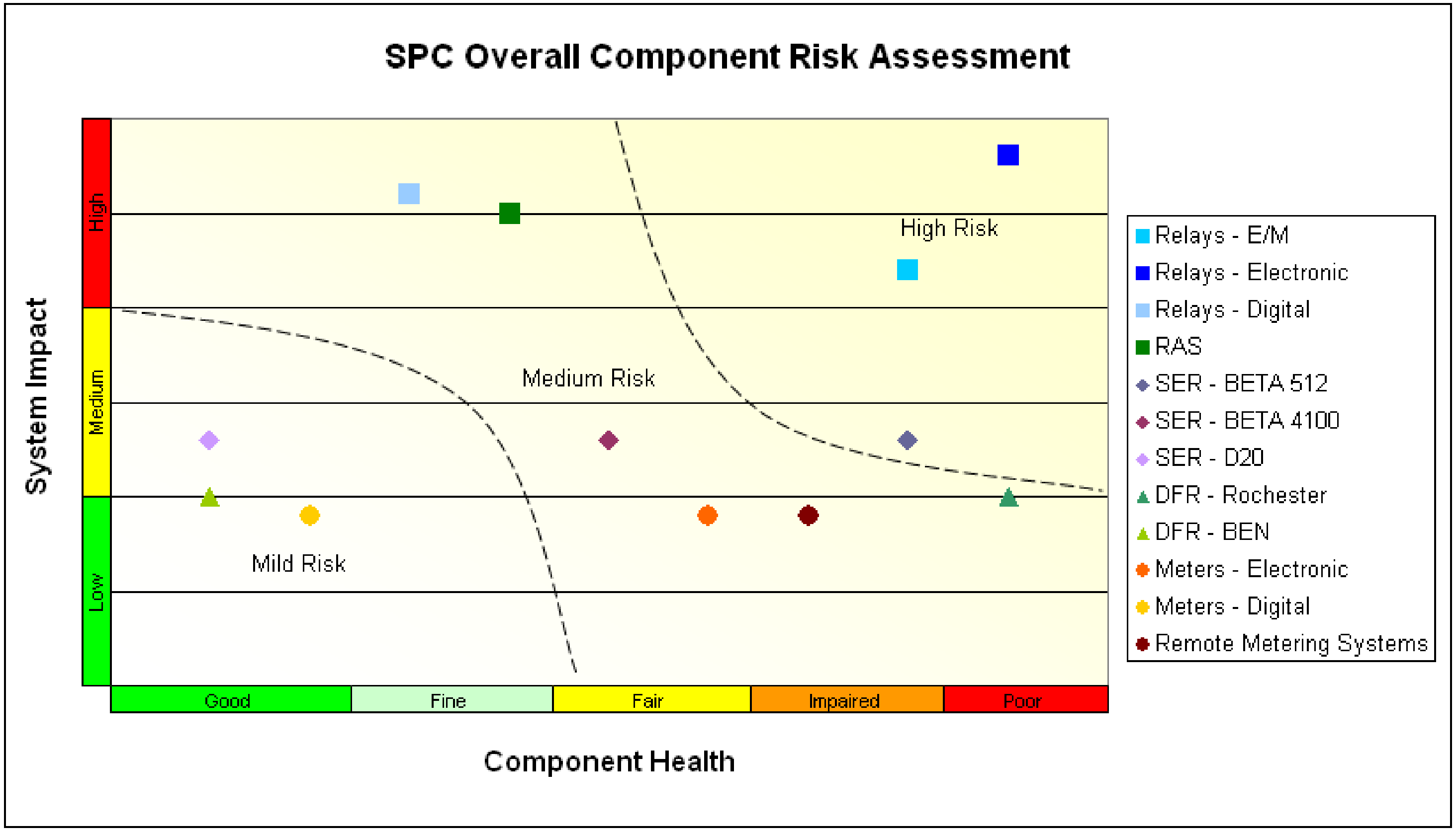
- SPC has made a concerted effort over the past few years to catch up on overdue maintenance to the point that the backlog is minimal; the small existing maintenance backlog consists of maintenance items that require scheduling customer participation and some low criticality items

## Capital Replacement Program in Recent Years

- Access to capital funds for discretionary replacement projects has been difficult in recent years and continues to be difficult despite the establishment of the Sustain Program and an approved business case
- Resources to commit to planning and submission of capital funding requests for SPC replacements has been limited
- Therefore the systematic strategy to replace SPC equipment has been only partially implemented
- Efforts to secure capital replacement funds have been focused on failing equipment that could no longer be maintained
- Overall, SPC equipment has been replaced at a much slower rate than it is aging toward obsolescence and poor condition

# Risks Assessment

- This risk assessment combines the equipment health rating with a system impact or criticality rating to develop a risk rating for SPC equipment groups



# Risks Assessment

- Overall risk assessment limitations and improvement opportunities:
  - Vertical axis, System Impact, is a broad qualitative measure used to compare relative criticality across SPC equipment categories; in order to develop a more quantitative risk assessment based on Priority Pathways, SPC equipment would need to be separated or weighted by function – protection and data gathering
  - Horizontal axis, Component Health, is based on a combination of maintainability and obsolescence from the charts on pages 31-32; to date these measures are based on SME input and do not have quantitative definitions and measures applied
  - The relay classifications digital, electronic and E/M contain equipment with large variation in criticality to the bulk electric system; so the points shown on the risk chart are general in nature
  - High, medium and mild risk areas on the risk map are broad divisions for graphic illustration

# Risks Assessment

- Relay specific risks:
  - A risk specific to electro-mechanical and electronic protective relays is that they have no data gathering capability like the modern digital relays; this means in the event of a fault or system equipment trouble in locations where no SER or DFR resides there is no ability to determine the exact cause; in instances where equipment on the customer's system was damaged or was the source of the problem, liability can fall on BPA unless data is available to understand the cause of the trouble and determine the exact source; in some cases the source of the trouble cannot be determined leaving opportunity for recurrence of the same problem
  - The INX5 bus differential relay is one model of electronic relay still in operation on the BPA system; this relay has no redundancy so it is a single point source of failure; failure of an INX5 relay requires deenergization of the protected substation bus until the relay can be repaired or replaced; this occurred on June 15, 2009 at Columbia substation where the bus section was deenergized for 27.5 hours until the relay could be repaired; INX5 parts are no longer available from the manufacturer so BPA is relying on cannibalized parts from INX5's that have been retired; a skeleton plan for temporary emergency replacement of this relay is in place but it requires a minimum of one week to install
  - 500kV electronic transmission line relays are obsolete so spare parts are being cannibalized from retired relays; these relays are redundant so single layer protection remains during failure of one relay set; however if the failure cannot be repaired, operational constraints come to play that may require de-rating or deenergization of the protected 500kV line; a WECC planning standard exists requiring redundant protective relays on the bulk electric system; if BPA were to operate a 500kV transmission line with single layer protection for an extended period of time awaiting replacement of a failed relay, a failure, misoperation or delayed clearing of a system fault could have a system wide impact and bring BPA under regulatory scrutiny

What equipment and facilities are covered?

What performance objectives, measures and targets should be set?

What is the health of the assets, and what risks must be managed?

**What strategies should we undertake?**

What will it cost?

# Strategy Development and Program Costs

- The following slides on Strategy Development and Program Costs do not include the results of the Integrated Control System Strategy (ICSS) that is currently underway and is due to be completed by Feb 2012.
- The Strategy Development and Program Costs sections of the presentation will be updated with the results of the ICSS at the conclusion of the ICSS project.
- Note that the SPC Sustain Program is not performing in accordance with the strategy as stated in the following slides. This is due to resource constraints and the current business environment.

# Strategy Development

- The condition and risk issues described previously are a result of the current approach to managing SPC assets. This “Momentum Strategy” is not sustainable:
  - Asset condition will continue to deteriorate, while the risks escalate.
  - Maintenance costs will increase and emergency capital replacements will become the norm.
  - Reliability will be compromised and emergency replacements will disrupt planned work.

- A new strategy for managing SPC assets is required:
  - The asset objectives described earlier will be met through a combination of accelerated replacements to restore asset condition, followed by a sustained investment program to maintain asset performance at objective levels.

# Strategy Development

## Protective Relays: with **poor health** assessment

- A significant number of protective relays are assessed to have poor asset health
- Of all SPC equipment, relays in this condition pose the largest risk to system reliability
- Protective relays in poor asset health are unacceptable so this equipment should be replaced as quickly as possible; SPC recommends a 5 year replacement plan
- Relays assessed in poor health based on maintainability and obsolescence are listed in the following table
- Required replacement rates to accomplish this objective with projects on 2 year work plans:
  - 13 lines per year (26 relay terminals, replacing relays at both ends of each line)
  - 13 bus differential relays per year
- The INX5 bus differential relay package has no redundancy therefore replacement with the new standard relay package provides the additional benefit of redundant protection where it presently does not exist

| Voltage | Protected Equip | Electronic Relay Model | Number of Relay Terminals |
|---|---|---|---|
| 500kV | Line | RALDA, RALZA, RALZB, RAZFE, LZ96 | 81 |
| 500kV | Line | LCB II | 8 |
| 230kV | Line | LCB II | 12 |
| | | Total line relay terminals: | 101 |
| | | | |
| 500kV | Bus | INX5 | 2 |
| 115, 230kV | Bus | INX5 | 48 |
| | | Total bus differential relay terminals: | 50 |

# Strategy Development

## Protective Relays: with **impaired health** assessment

- A large number of protective relays are assessed to have impaired asset health
- These are electro-mechanical relays that are obsolete and becoming more difficult to maintain because of aging components and a dwindling supply of spare parts
- In order to prevent these relays from slipping into poor health prior to replacement, SPC recommends a 10 year replacement plan
- Relays assessed in impaired health based on maintainability and obsolescence are listed in the table on the following page; the table includes average replacement rates on a 10 year plan for each category
- Cost, criticality of protected equipment and ability to get outages for construction vary widely across this relay category
- There are a number of plans that could be used to implement this strategy, 3 of them are:
  - Typically the higher criticality equipment has higher replacement costs so based on the average annual cost to accomplish this 10 year plan do as many of the most critical (this will be the 500kV relays) replacements as possible in the given average annual budget
    - Advantage: most critical equipment is replaced first
    - Disadvantage: this concentrates required outages on the 500kV system in the first 3 or 4 years of the 10 year plan; it may be impossible to get all of these outages given the number of 500kV outages that will be required to accomplish the 5 year replacement plan for the equipment in poor health
  - Spread the required replacements in each category equally across the 10 year plan
    - Advantage: less pressure on the system for 500kV outages and lower voltage equipment is not being ignored for several years while the higher voltage equipment is replaced
    - Disadvantage: some critical equipment will wait longer before being replaced
  - Focus on replacement of the lower voltage equipment during the first 5 years while the 5 year plan to replace poor health equipment (which is primarily 500kV) is being accomplished
    - Advantage: minimizes outage pressure on 500kV system and gets a lot of lower voltage equipment replaced early in the plan; focuses replacement where there is more direct benefit to the customer
    - Disadvantage: most critical equipment is left until the second half of the 10 year plan

# Strategy Development

| Electro-Mechanical Relays (Impaired asset health) | | | |
|---|---|---|---|
| Voltage | Protected Equip | Number of Relay Terminals | Replacements per year on 10 year plan |
| 500kV | Line | 30 | 4 |
| 69-345kV | Line | 275 | 28 |
| <69kV | Feeder | 123 | 13 |
| | Total Line: | 428 | |
| | | | |
| 500kV | Bus Differential | 19 | 2 |
| 69-345kV | Bus Differential | 86 | 9 |
| 69-345kV | Bus Tie/Section | 25 | 3 |
| | Total Bus: | 105 | |
| | | | |
| >50MVA | Transformer | 176 | 18 |
| <50MVA | Transformer | 40 | 4 |
| | Total Xfm: | 216 | |
| | | | |
| All | Shunt Caps & Rectors | 57 | 6 |
| | | | |
| | Grand Total: | 806 | 81 |

# Strategy Development

Sequential Event Recorders: with **poor health** assessment

- The BETA 512 sequential event recorders are assessed to be in poor health primarily due to their obsolescence
- Because they have a data gathering function compared to the system protection function of the relays, their system impact in the event of failure is less
- Presently 83 of these units are in operation on the system
- Although poor asset health is not considered acceptable the urgency of replacing these SER’s is less than for relays in the same condition based on lower system impact in the event of failure
- SPC recommends an 8 year replacement plan for this equipment
- This would require replacement of 10 or 11 units per year

# Strategy Development

## Digital Fault Recorders: with **poor health** assessment

- 23 Rochester DFR's are in operation and all are assessed to be in poor condition
- 13 have been funded for replacement in FY2011-12
- The remaining 10 are scheduled for replacement by FY2017

## Revenue and Interchange Meters: with **fair health** assessment

- The analog JEM1 meters are still able to be maintained and are not expected to slip into an impaired or poor health rating within the next 5 years
- To prevent the JEM1 meters from deteriorating to poor health prior to replacement, SPC recommends replacement of these meters on a 12 year plan
- Focus will be on replacing interchange and AGC meters due to the combined obsolescence of the meter and the integral EXJ register
- RMS units assessed in impaired condition are a minor unit in the Plant Catalog; SPC has a standard "plug and play" replacement so these units are being replaced using expense funds when the units fail prior to meter replacement

## Control and Indication:

- While further condition assessment of this equipment is underway, $500k/yr is recommended for replacement of the SCU's and $2.5M/yr for mini control consoles, unless a lower cost alternative can be designed. This is being worked on by the design groups.

What equipment and facilities are covered?

What performance objectives, measures and targets should be set?

What is the health of the assets, and what risks must be managed?

What strategies should we undertake?

**What will it cost?**

# Forecast Planning Levels

## Forecast SPC planning levels:

- The momentum planning levels assume a replacement rate similar to the last 8 to 10 years
- O&M is linearly extrapolated from actual data for 2003 to 2009
- Emergency capital replacements will become commonplace
- Only direct capital costs of emergency replacements are considered; there will also be indirect costs from unplanned outages such as customer outages, planned outage cancellations and disruption to normal maintenance and construction processes
- Emergency replacements typically cost more due to overtime labor used to rush the project to completion
- The momentum planning levels are provided for reference; as discussed earlier, the momentum strategy is not considered to be viable

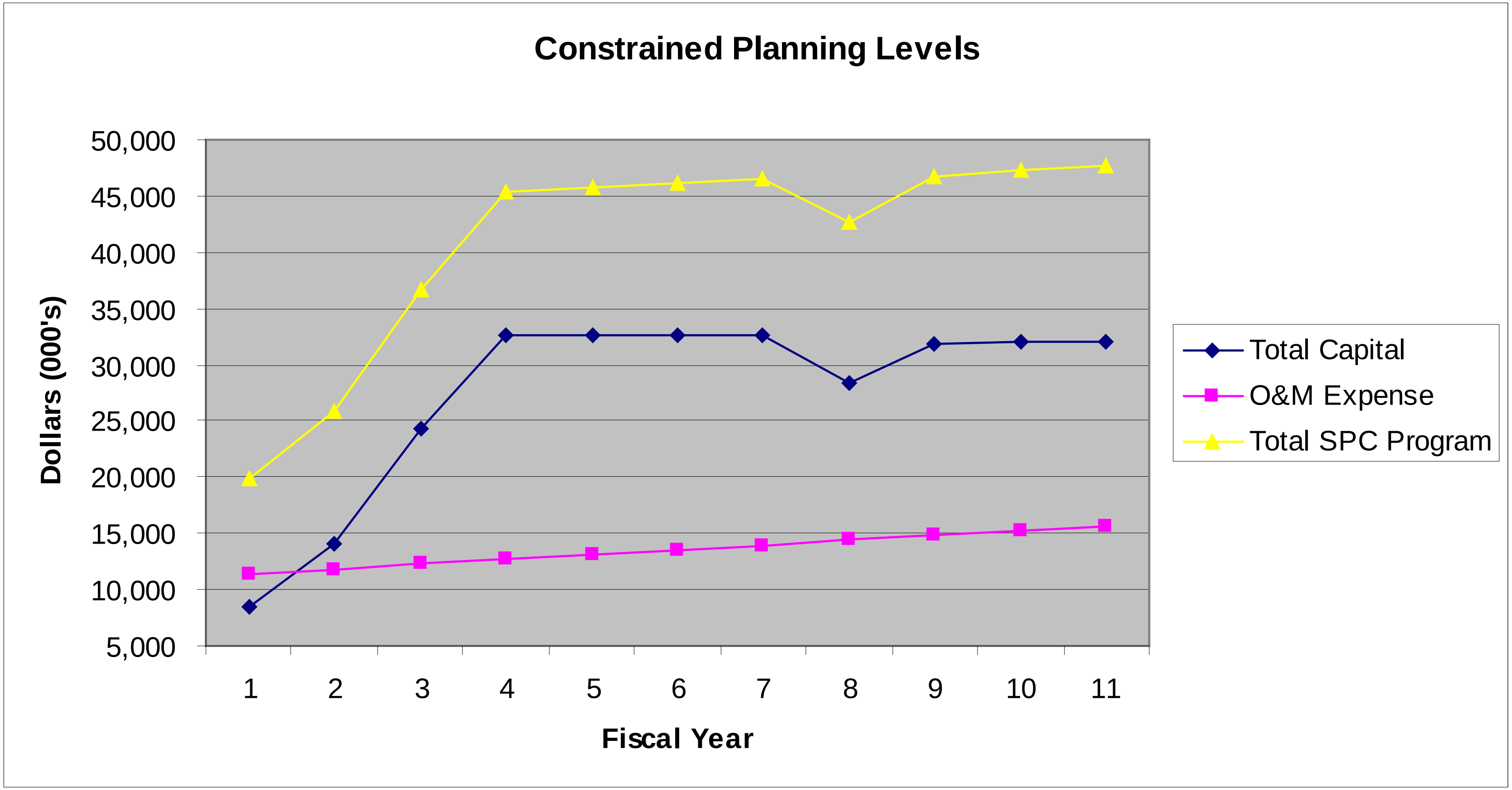
# Forecast Planning Levels

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.

## SPC - Constrained Planning Levels

| *Dollars in Thousands* | FY 2011 | FY 2012 | FY 2013 | FY 2014 | FY 2015 | FY 2016 | FY 2017 | FY 2018 | FY 2019 | FY 2020 | FY 2021 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Relays** | | | | | | | | | | | |
| Strategy Driven Replacements | 3,546 | 9,726 | 20,440 | 28,179 | 28,179 | 28,179 | 21,828 | 15,477 | 15,477 | 15,477 | 15,477 |
| Replacements to Maintain Condition | - | - | - | - | - | - | 2,000 | 4,000 | 8,000 | 8,000 | 8,000 |
| Total Capital | 3,546 | 9,726 | 20,440 | 28,179 | 28,179 | 28,179 | 23,828 | 19,477 | 23,477 | 23,477 | 23,477 |
| **Sequential Events Recorders** | | | | | | | | | | | |
| Strategy Driven Replacements | 1,338 | 3,122 | 2,964 | 2,964 | 2,964 | 2,964 | 2,964 | 2,964 | 1,482 | - | - |
| Replacements to Maintain Condition | - | - | - | - | - | - | - | - | 1,000 | 2,000 | 2,000 |
| Total Capital | 1,338 | 3,122 | 2,964 | 2,964 | 2,964 | 2,964 | 2,964 | 2,964 | 2,482 | 2,000 | 2,000 |
| **Fault Recorders** | | | | | | | | | | | |
| Strategy Driven Replacements | 3,338 | 235 | - | - | - | - | - | - | - | - | - |
| Replacements to Maintain Condition | - | - | - | - | - | - | - | - | - | 750 | 750 |
| Total Capital | 3,338 | 235 | - | - | - | - | - | - | - | 750 | 750 |
| **Revenue and Interchange Meters** | | | | | | | | | | | |
| Strategy Driven Replacements | 250 | 500 | 500 | 1,000 | 1,000 | 1,000 | 5,350 | 5,350 | 5,350 | 5,350 | 5,350 |
| Replacements to Maintain Condition | - | - | - | - | - | - | - | - | - | - | - |
| Total Capital | 250 | 500 | 500 | 1,000 | 1,000 | 1,000 | 5,350 | 5,350 | 5,350 | 5,350 | 5,350 |
| **Control and Indication** | | | | | | | | | | | |
| Strategy Driven Replacements | - | 500 | 500 | 500 | - | - | - | - | - | - | - |
| Replacements to Maintain Condition | - | - | - | - | 500 | 500 | 500 | 500 | 500 | 500 | 500 |
| Total Capital | - | 500 | 500 | 500 | 500 | 500 | 500 | 500 | 500 | 500 | 500 |
| **SPC Total** | | | | | | | | | | | |
| Strategy Driven Replacements | 8,472 | 14,083 | 24,404 | 32,643 | 32,143 | 32,143 | 30,142 | 23,791 | 22,309 | 20,827 | 20,827 |
| Replacements to Maintain Condition | - | - | - | - | 500 | 500 | 2,500 | 4,500 | 9,500 | 11,250 | 11,250 |
| Total Capital | 8,472 | 14,083 | 24,404 | 32,643 | 32,643 | 32,643 | 32,642 | 28,291 | 31,809 | 32,077 | 32,077 |
| O&M Expense | 11,388 | 11,817 | 12,247 | 12,676 | 13,105 | 13,535 | 13,964 | 14,393 | 14,823 | 15,252 | 15,681 |
| Total SPC Program | 19,860 | 25,900 | 36,651 | 45,319 | 45,748 | 46,178 | 46,606 | 42,684 | 46,632 | 47,329 | 47,758 |

# Forecast Planning Levels



## BPA's Financial Disclosure Information

- All FY 2010 – FY 2017 information has been made publicly available by BPA on May 13th, 2010 and does <u>not</u> contain Agency-approved Financial Information.
- All FY 2003 – 2009 information has been made publicly available by BPA and contains Agency-approved Financial Information.
- All FY 2011 Rate Case data has been developed for publication in rates proceeding documents and is being provided by BPA.

# Forecast Planning Levels

- Typical replacement costs used in planning level estimates

| Voltage | Protected Equipment | # of Terminals | Cost per Terminal | Total |
|---|---|---|---|---|
| Relays on 5 year replacement plan: | | | ($1000's) | ($1000's) |
| 500kV | Line | 89 | $500 | $44,500 |
| 230kV | Line | 12 | $230 | $2,760 |
| 500-115kV | Bus Diff | 50 | $325 | $16,250 |
| Relays on 10 year replacement plan: | | | | |
| 500kV | Line | 30 | $500 | $15,000 |
| 69-345kV | Line | 275 | $150 | $41,250 |
| <69kV | Feeder | 123 | $80 | $9,840 |
| 500-69kV | Bus Diff | 105 | $325 | $34,125 |
| 69-345kV | Bus Tie/Section | 25 | $190 | $4,750 |
| >50MVA | Transformer | 176 | $200 | $35,200 |
| <50MVA | Transformer | 40 | $80 | $3,200 |
| All | Shunt Caps & Rectors | 57 | $200 | $11,400 |
| SER's on 8 year replacement plan: | | | | |
| 500-115kV | BETA 512 | 83 | $250 | $20,750 |
| Meters on 12 year replacement plan: | | | | |
| | JEM1 | 1260 | $27 | $34,020 |