Conservation Voltage Regulation (CVR)

A Chance for T&D and Energy Efficiency to Team Up

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Conservation Voltage Regulation

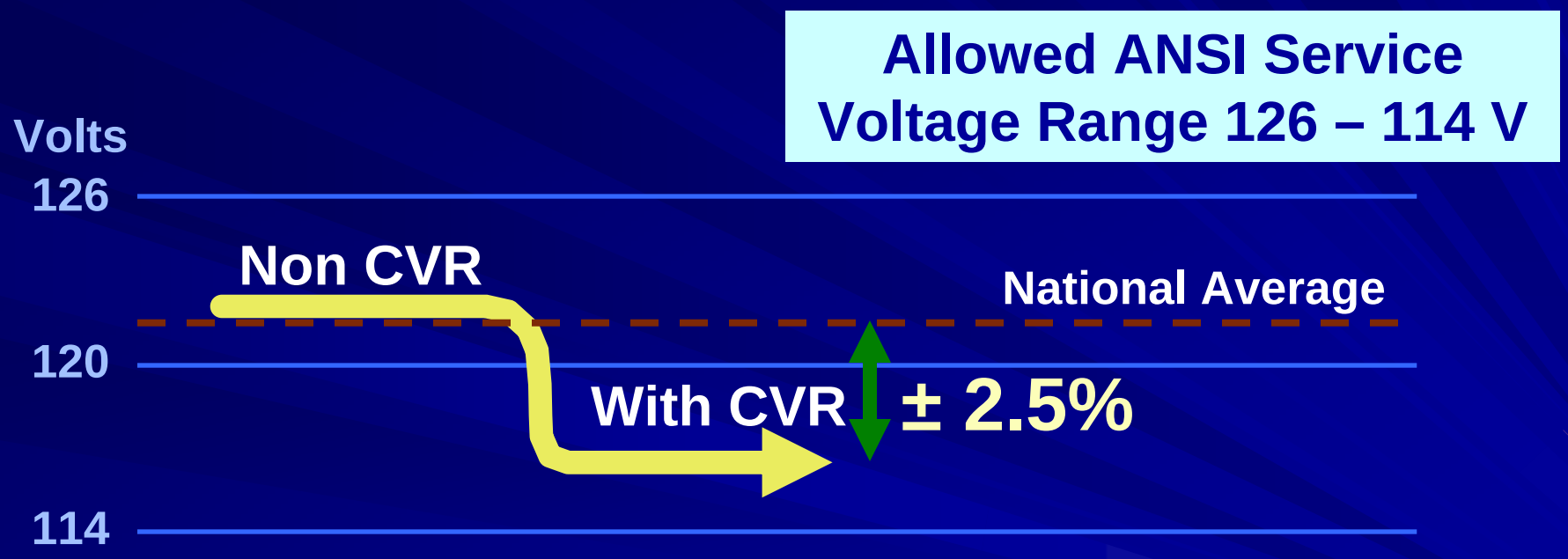
1. History of CVR and Voltage Optimization
2. Field Results - Snohomish and NEEA DEI
3. BPA Distribution Efficiency Incentive Program
4. Simplified M&V protocols
5. Voltage Optimization Methods
6. Business Case for Distribution Efficiency
7. Obstacles in implementing CVR
8. Advances in Distribution Systems

History of CVR

- It started with the development of REA design and operation guidelines in 1940's
- REA (RUS) Bulletins specified ways to provide optimal voltage levels at the customer meter
- Utilities stopped the practice of lower voltage in the 1960's
- The California PUC required lower voltages to conserve energy in the 1970's hence CVR

Conservation Voltage Regulation

Average Customer Service Voltage



90% of Homes Receive Too Much Voltage

- California Utilities performed CVR research in 1970's
  - 5% Voltage Reduction ~ 5% reduction in Energy Usage and Demand
- California PUC directed Utilities to lower voltage in 1976
  - Modify Service Voltage to 120 +0/-5% = 114-120V
- In Early 1980's, ERPI Project 1419 conducted CVR tests
  - Detroit Edison and TESCO (1982), TVA (2008)
- Northwest Utilities conducted CVR tests in Late 1980's
  - SCL, Pacific Power, and Snohomish
- NEEA conducted DEI research in 2003 - 2007
  - Load Research and Pilot Demonstrations with 13 Northwest utilities
- Current NW CVR Applications
  - Snohomish, Clark, Lakeview L&P, Eatonville, Tacoma, Idaho Power, …..

Results of Field Tests

Distribution
System Pilots

Load
Research

Results of Field Tests

- Results of Field Tests indicate

  CVR Factor (Δ E/ Δ V) =0.5 to 1.5

- Characteristic Load Models can determine expected savings for known utility load characteristics
- Commercial energy saving greater than Residential
- Demand reduction % is higher than energy saving %
- System Losses (transformers & lines) are reduced
- Loss Revenue handled same as conservation measures
- End Use Appliances operate cooler with extended life

Results of Field Tests

- CVR Energy Saved (%) is calculated from reduced customer voltage

  $= \Delta E / \Delta V \times \Delta V \times$ Distribution Substation Annual kWh

- Total Distribution energy savings (0.6% to 2.0%)

  = CVR Energy Saved + Distribution Loss reduction

- Distribution Improvements to reduce system Loss
  - ✓ Feeder Load Balance by phase < 15% or better
  - ✓ Feeder power factor >97% or better
  - ✓ Feeder max voltage drop <3.3% or better
  - ✓ Feeder max voltage drop ± 20% of system average drop

Snohomish Field Tests

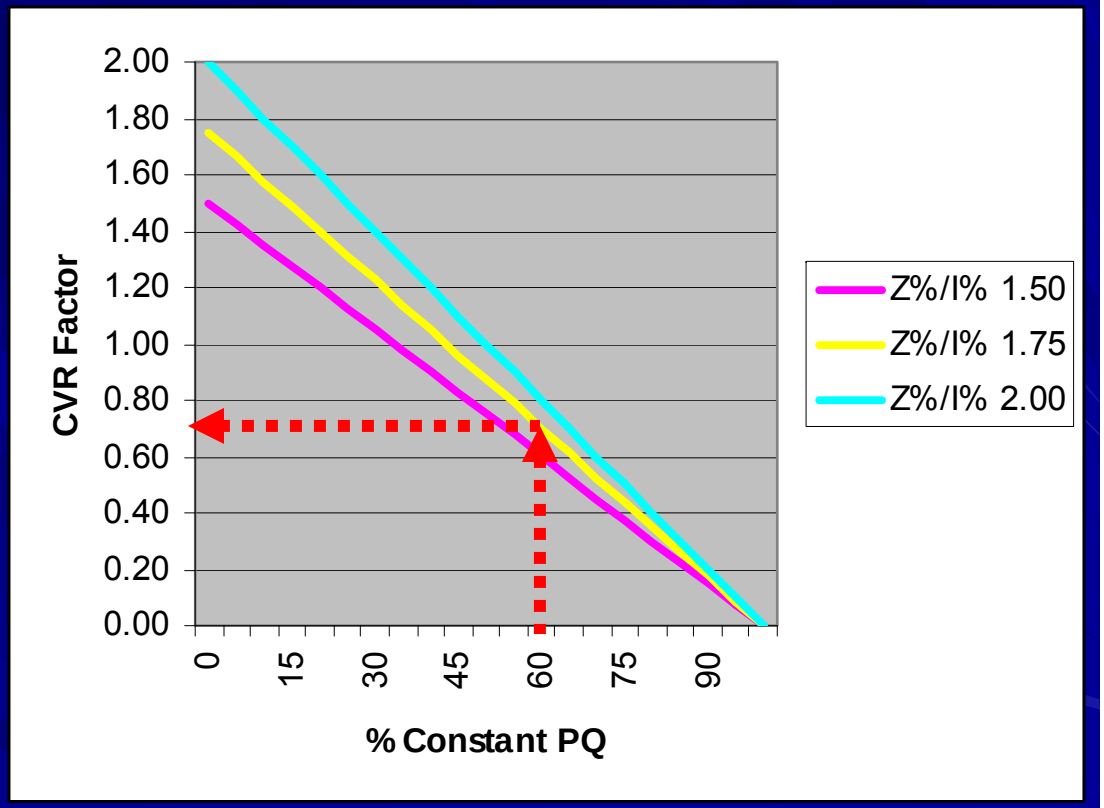
1988 -1992 CVR Research & Development
Two Substations, 9 feeders, 10,000 Customers
Results Verified by BPA

Constant Power Load includes Resistive Heat Load and Some Air Conditioning Load

Typical Average Load Characteristics

%I, %Z, %PQ

14.5, 25.5, 60.0



CVR Factor = ΔE Saved / ΔV (AVG) Reduction

Snohomish CVR Experience

- Installed CVR from 1992 to 2006
  - ✓ 68 substations
  - ✓ 272 feeders
  - ✓ 290,000 customers
- Equipment and Systems Installed
  - ✓ LDC voltage controls
  - ✓ Voltage regulators
  - ✓ Capacitors
  - ✓ Line reconductoring
  - ✓ System metering
  - ✓ Advanced engineering modeling and tools

Snohomish CVR Experience

- Total Installed Cost $4,614,000 with << 5% Annual O&M
- Energy Savings 53,856 MWh/yr, 6.15 aMW, <$12/MWh
- Average customer voltage reduction is 2.3% with CVR*f* 0.70
- Typical feeder has 1.61% energy savings of 198 MWh/yr
- Reduced distribution system losses 11,226 MWh/yr
- No low voltage complaints experienced
- Improved customer voltage quality (less voltage swing)
- Average Customer saved 1.32% or 156 kWh/yr saved

NEEA DEI Study

The NEEA DEI Study (2002-2007) involved 13 Northwest Utilities to study the impacts of lower voltage at the customer.

– Avista	Pilot
– Clark Public Utilities	Load Research & Pilot
– Douglas PUD	Load Research & Pilot
– Eugene W & EB	Load Research
– Franklin PUD	Load Research
– Hood River	Load Research
– Idaho Falls Power	Load Research
– Idaho Power	Load Research & Pilot
– PacificCorp	Load Research
– Portland Gen Elec	Load Research
– Puget Sound Energy	Load Research & Pilot
– Skamania PUD	Load Research
– Snohomish PUD	Load Research & Pilot

Contractor was R.W. Beck, RLW Analytics, Auriga, and Hunt Power

NEEA DEI Study Results

- Load Research – 2.5 years of data
  - ✓ 395 Random Northwest locations – 11 utilities
  - ✓ Several climate zones and customer classes
  - ✓ Measured average customer voltage 120.7 V
  - ✓ Average voltage reduction 5.20 V (4.3%)
  - ✓ kWh CVR*f* = 0.569
  - ✓ kVAr CVR*f* = 3.350

NEEA DEI Study Results

- Pilot Demonstrations – 2.5 years of data
  - ✓ 10 Distribution Substations – 6 utilities
  - ✓ 30,000 customers involved in tests
  - ✓ Average voltage reduction 3.03 V (2.5%)
  - ✓ Average energy saved 2.07%
  - ✓ kWh CVR*f* = 0.690
  - ✓ kW CVR*f* = 0.780
  - ✓ kVAr CVR*f* = 3.850

NEEA DEI Study Deliverables

- NEEA DEI Final Report December 2007
  - ✓ Results of Study
  - ✓ Regional Savings Projections
- DEI Efficiency Guidebook
- DEI Efficiency Calculator
  - ✓ Software tool to guide energy efficiency improvements
  - ✓ Includes Management and Engineering components
- DEI Final Report Available from NEEA

  http://www.nwalliance.org/ourwork/projectsummary.aspx?ID=75

Distribution Efficiency BPA Incentive VO Program

- Distribution System *Efficiency Incentives* are offered by BPA for loss reduction and voltage optimization projects with CRC and CAA
- The existing *CVR Protocol #1* M&V process is costly and requires one year of data collection and analysis
- BPA is planning to formulate, develop, and evaluate new *Simplified CVR M&V protocols* by June 2009 using the IPMVP standards
- BPA will conduct *Training Workshops* in July-October 2009 describing the use of simplified protocols and how to design efficient distribution systems

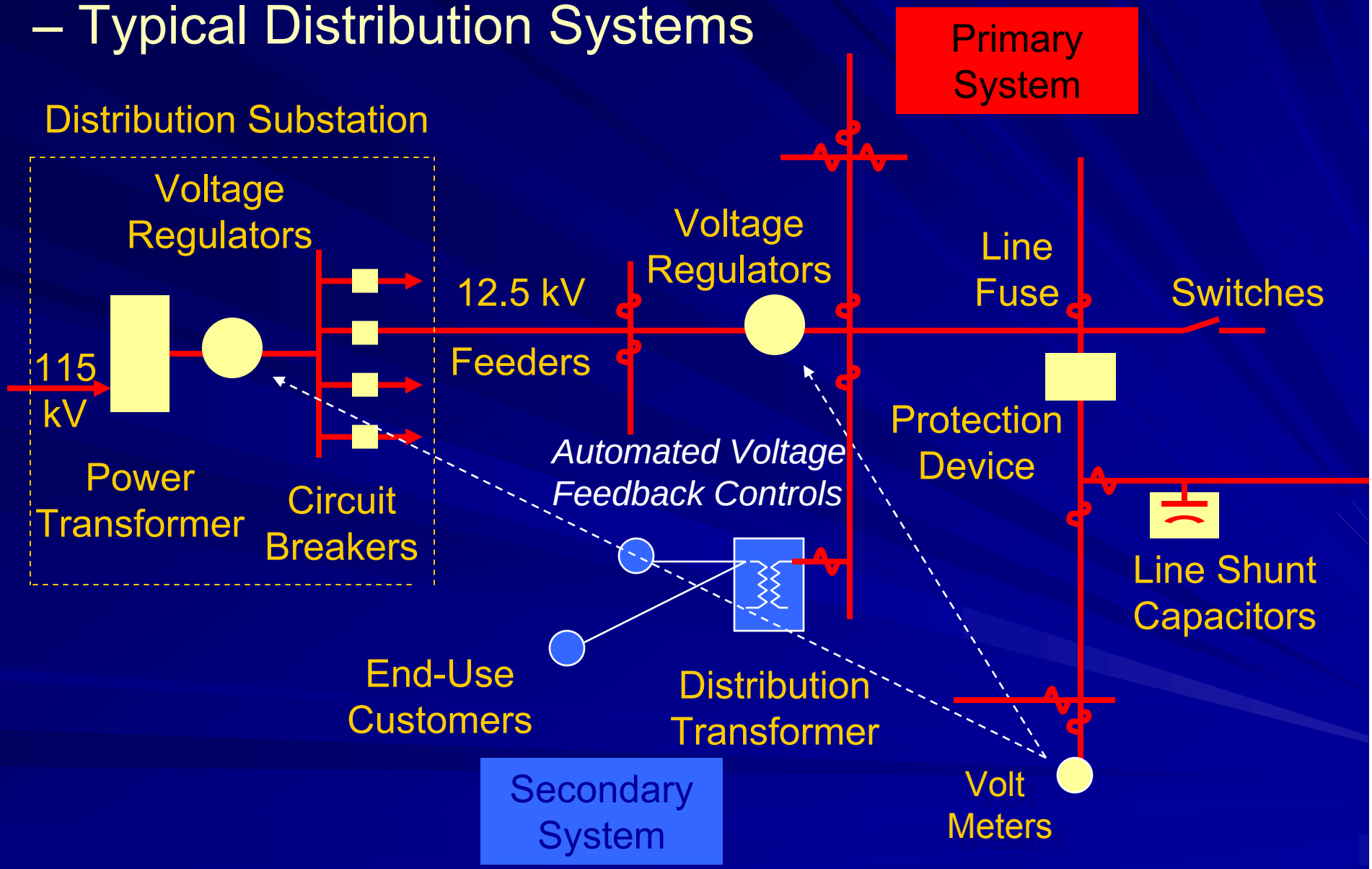
Benefits of Simplified VO M&V Protocols

- The *Application Process* to Obtain Distribution System Efficiency Incentives is simplified
- *Energy Savings* are determined from calculations using IPMVP Option D approach calibrated with baseline data
- Calculation methods are based on the *NEEA DEI Efficiency Calculator*
- The Utility can receive *Prompt Payment* from efficiency incentive program with less review time

Benefits of Simplified VO M&V Protocols

- Efficient distribution *Project Designs* can be based on maximizing the incentive benefits
- *Verification Activities* are simplified
- NWPCC distribution system *Energy Savings Forecasts* are improved
- Utility distribution system *Sustainable Efficiency* is encouraged

– Typical Distribution Systems



Distribution System Line Equipment Needed for VO

- Capacitors & Regulators
- Re-Configuration lines
- Feeder Increase Phases
- Line Reconductoring
- Distribution Transformers Replacements
- Secondary Conductor Reconductoring
- Substation, Regulator, & EOL Metering
- Voltage Controls on Regulators
- Voltage Sensing at regulators and EOL

Distribution System VO Minimum Requirements

- System Metering
  - ✓ Substation kW, kvar, and voltage recording
  - ✓ Feeders kW and kvar recording
  - ✓ EOL Voltage Recording
- System Requirements (improvements may be needed)
  - ✓ Feeder Load Balance by phase < 15% or better
  - ✓ Feeder power factor >97% or better
  - ✓ Feeder max voltage drop <3.3% or better
  - ✓ Feeder max voltage drop ± 20% from system avg

Distribution System Voltage Optimization Methods

- Voltage Fixed Reduction (VFR)

  Voltage reduction is fixed amount at regulators with volt sensing only at voltage regulators

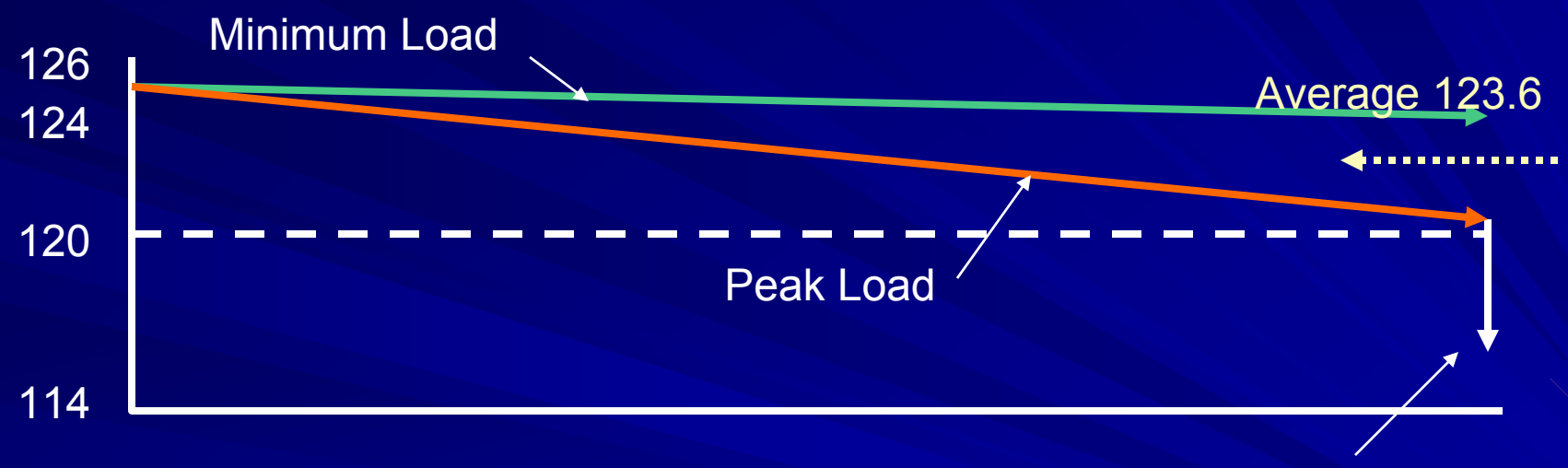
- Line Drop Compensation (LDC)

  Voltage is controlled using Line Drop Compensation Controls at regulators with volt sensing only at regulators

- Automated Voltage Feedback Control (AVFC)

  Voltage is controlled using automatic feedback controls at regulators with volt sensing at regulators and EOL

Baseline Voltage Regulation

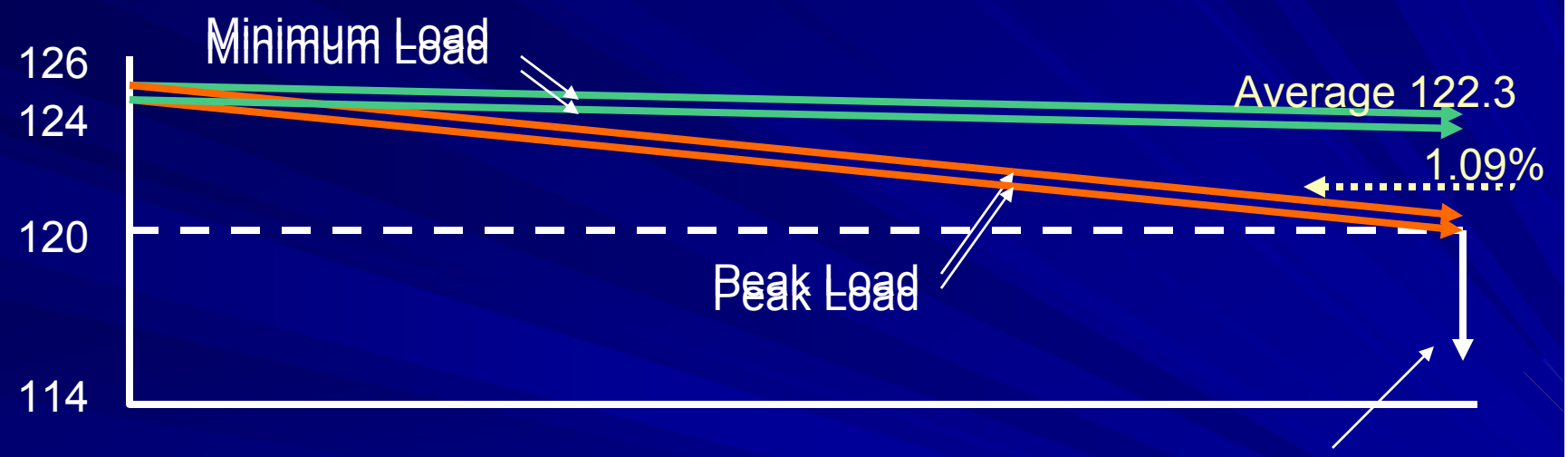


- Voltage Fixed at regulator

Primary Min 122.5 V

Customer Min 118.9 V

Voltage Fixed Reduction VFR



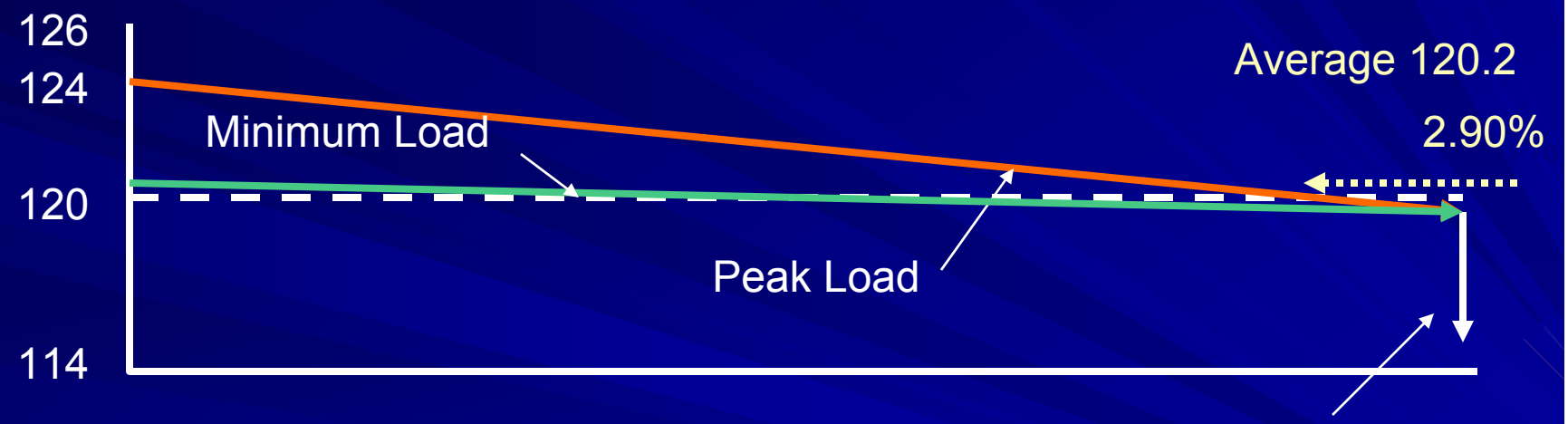
Assumed Secondary 3.6 V Drop (3.0%)

Primary Min 121.2 V

Customer Min 117.6 V

- Voltage Fixed at regulator

Line Drop Compensation LDC



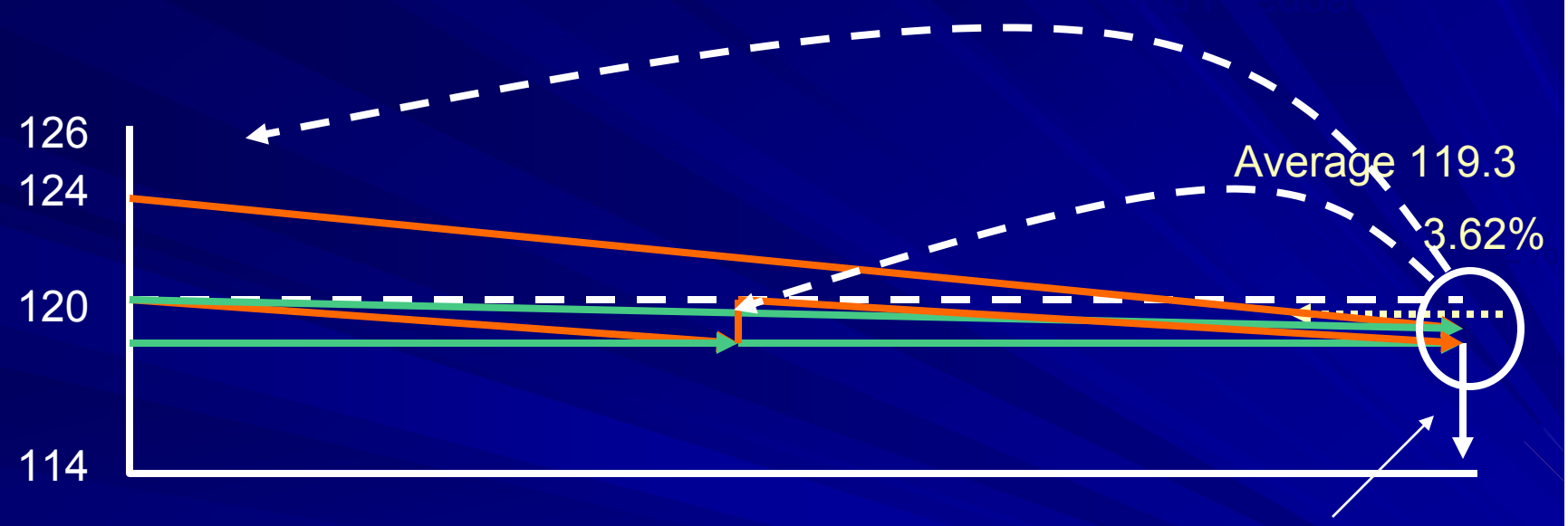
Assumed Secondary 3.6 V Drop (3.0%)

Primary Min 118.8 V

Customer Min 115.2 V

- Voltage Varies at Regulator proportional to load

Automated Voltage Feedback Control AVFC



- Voltage Varies at Regulator based on EOL voltage sensing

Primary Min 118.6 V

Customer Min 115.0 V

Typical Substation Area Energy Savings

Distribuiton Efficiency ECM Measure	Site Energy Usage (MWh/yr)	Average Voltage Reduction	Typical CVR Factor	Total Site Energy Saved (MWh/yr)	Total Site Energy Saved (%/yr)
VFR	60,000	1.09%	0.69	451	0.75%
LDC	60,000	2.90%	0.69	1201	2.00%
AVFC	60,000	3.62%	0.69	1499	2.50%

- Site Energy Use range 30,000 to 200,000 MWh/yr (avg 60,000 MWh/yr)
- Site Demand range 7 MW to 45 MW (avg 14 MW)
- Site range 2800 to 18000 Customers (avg 5600)

Typical Substation Area Benefit Cost Ratio

Distribuiton Efficiency ECM Measure	Site Investment Costs	O&M cost ($/yr)	Total Annual Cost	Cost/kWh saved	Benefit / Cost Ratio
VFR	$20,000	$1,000	$3,196	$0.007	11.6
LDC	$90,000	$4,500	$14,382	$0.012	6.9
AVFC	$225,000	$11,250	$35,954	$0.024	3.4

Economic Assumptions:
15 Years of Savings Life
5% Annual O&M
7% Discount Rate
3% Inflation (installation & energy)
10% Capitalized rate of return
No salvage value credit for remaining equipment life

Purchase Power Cost $50 / MWh

Distribution System Efficiency Obstacles

- Lack of working relationship between Departments
- Lack of Financial Compensation for Energy Efficiency
- Lack of Incentives for Reducing System Losses
- Lack of utility long range loss reduction strategies
- Deficient engineering modeling and forecasting

Distribution System Efficiency Obstacles

- Misconception that Loss Revenue is unacceptable
- Misconception that CVR causes higher system losses
- Misconception that voltage complaints will increase
- Misconception that appliances will be damaged
- Misconception that system reliability will be reduced

Upcoming Green Circuit Implementation Initiatives

- Advanced Distribution System Modeling
  - GIS
  - Transformer Load Modeling
  - Primary & Secondary power flow modeling (120V)
  - Small Area Spatial load forecasting
  - Probability based planning
- Network Primary Operations
  - Closed looped systems
  - Enhanced automatic sectionalizing and voltage control

Upcoming Green Circuit Implementation Initiatives

- Advanced Customer Load Modeling
  - Plug-In EV (energy and storage at 120 V)
  - Demand Control and Demand Response
  - Time of Use
  - Performance Based Rates
  - Dispersed Generation
  - Advanced Predictive Reliability Models
- Optimization Decision Models
  - Operations, maintenance and capital planning
  - Predictive Reliability Modeling & Automated Design

Comments and Questions