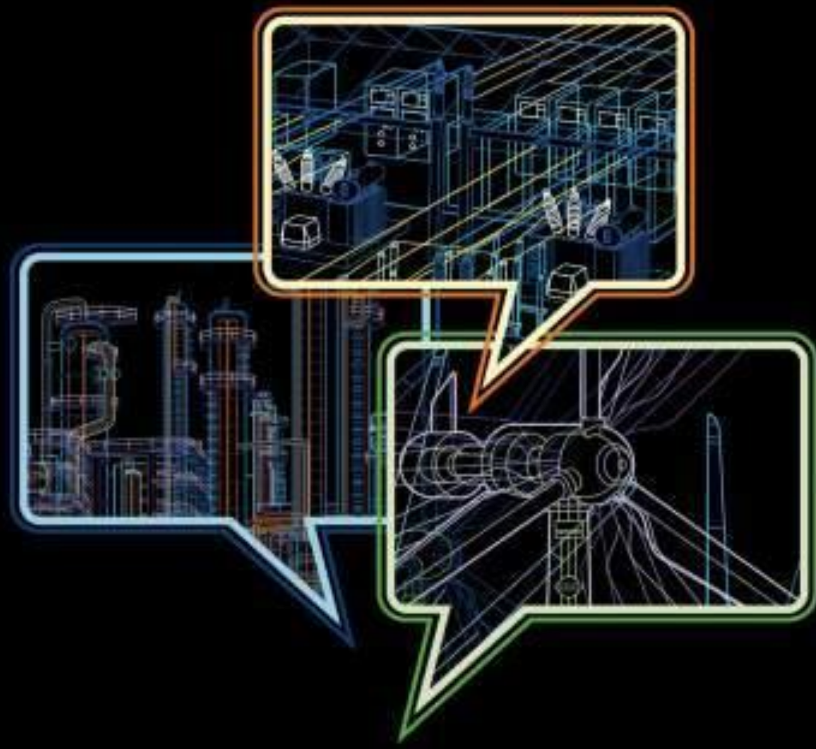

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EPO-139-1
Benefits of Deploying a Volt-VAr Management System

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Benefits of Deploying a Volt-VAr Management System

- Speaker name: Ron Presti
- Speaker title: Sr Product Manager
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- Location: Bedford, MA

Co-presenter

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- Speaker title: Marketing and Sales Manager
- Company name: ABB Inc.
- Location: Pinetops, NC

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Please be aware of these emergency procedures

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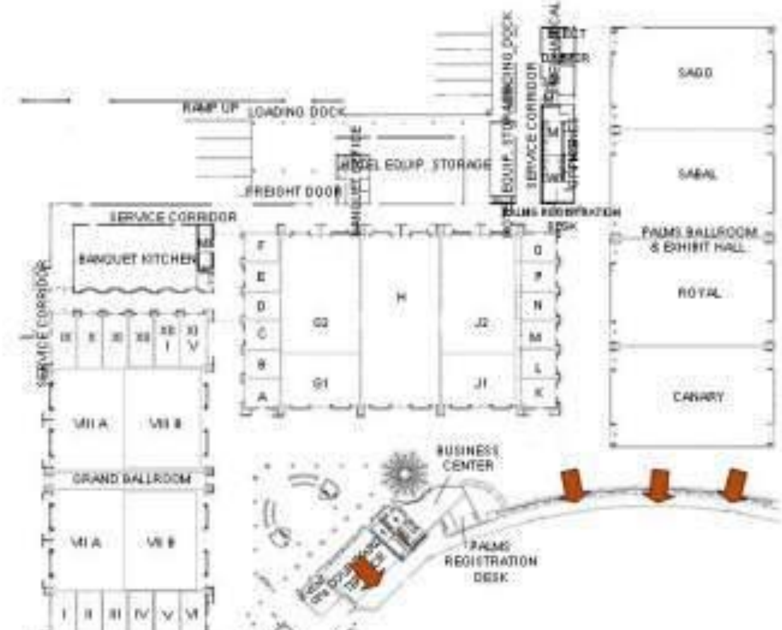
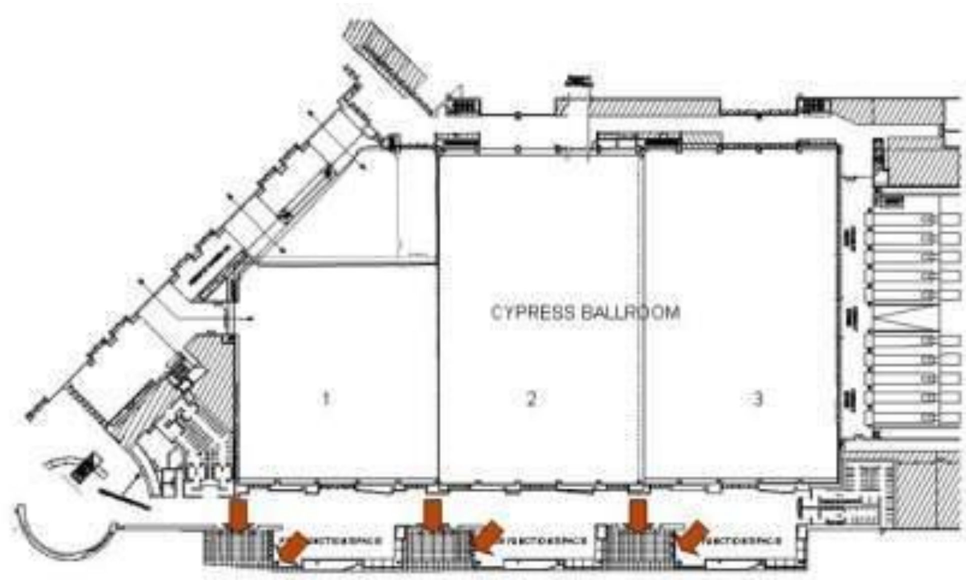
Your safety is important to us
Convention Center exits in case of an emergency





Know your surroundings:
- Identify the meeting room your workshop is being held in
- Locate the nearest exit

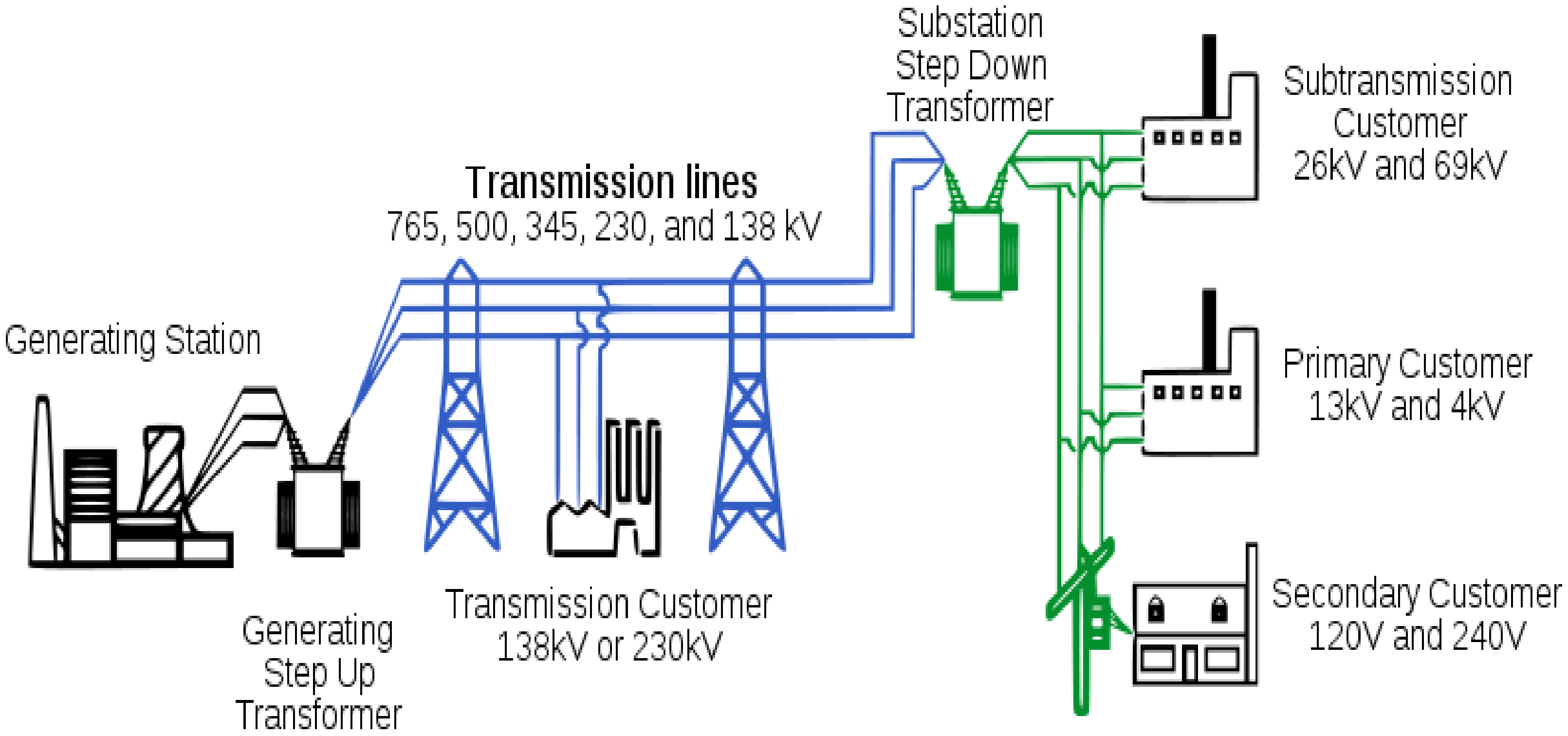
Benefits of Deploying a Volt-Var Management System
Workshop Goals

Provide Answers to the following Questions

1) What are VArs and how do they impact the Distribution System
2) How can Energy Demand be reduced by Voltage Reduction
3) What is a Volt-VAr Management System
4) What are the Key Benefits of a VVMS
5) How can Sensors improve performance of a VVMS

Energy Efficiency and Demand Reduction

- All stages of the power delivery system, from generation to consumer, are improving there energy efficiency in an effort to conserve resources.



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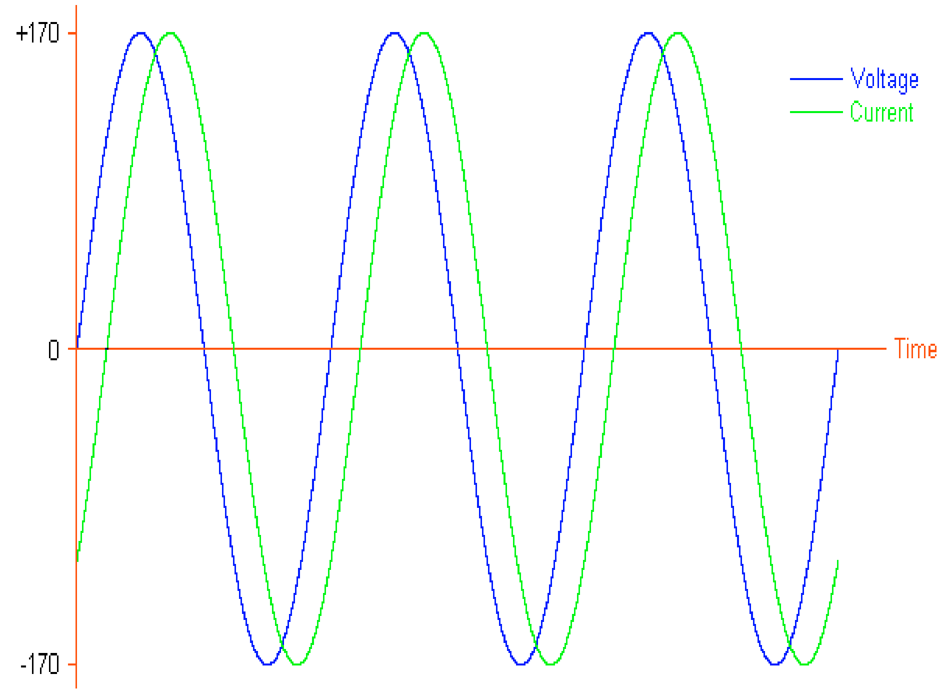
Distribution Losses

- Typical Distribution losses range from 3% to 9% of delivered power
- Account for more than 40% of power system losses.
- Sources of Distribution Loss
  - Step-Down Transformer Losses (including No-Load Losses)
  - Conductor Resistance (I^2R losses)
  - Reactive Power losses (VArs)

VArs – What are they?

AC circuits have the following power components…

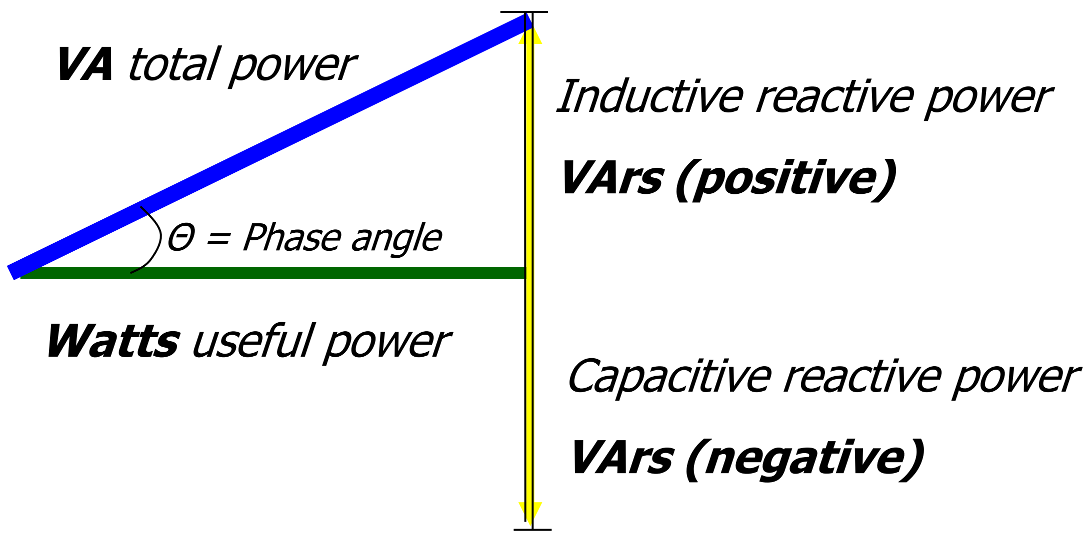
- VA – Apparent Power (Total Power)
- Watts – Real Power
- VAr – Volt-Ampere Reactive
- VArs occur as a result of a phase shift between the AC Voltage and AC Current.
- This phase shift caused by Inductive loads such as Motors, Air Conditioners, etc.
- VArs Impact distribution efficiency by reducing power factor thus increasing infrastructure loads
- PF = Watts (Delivered Power) / VA (Generated Power)



Current “Lags” Voltage

Total Power is a combination of Watts (resistive) and VArs (reactive).

The AC Power Triangle



VA = Volt Amperes = SQRT (Watts^2 + VArs^2)

For Θ = 45º , If W = 1 then VAr = 1

VA = SQRT(1+1) = 1.4 VA

Feeder VArs from a Business Perspective

VArs on feeder circuits are costly!!

VArs diminish Infrastructure Capacity **(transformers and wires)**

VArs increase capital requirements

Reduce reserve infrastructure capacity,
Prematurely necessitate major construction,
Expose capital dollars unnecessarily.

VArs increase Energy Consumption **(waste energy)**

VArs increase the cost of energy

Increased energy (VAh) consumption
Increased peak demand,
Increased demand penalties,
Increased power factor penalties

VArs deform Voltage Profiles **(poor power quality)**

VArs reduce power quality and meter revenue

VArs decrease down-line voltages,
Lowered voltages reduce kWh revenue

Demand Reduction via Conservation Voltage Reduction

- Reduce Voltages to lower limit of regulated level of 114V
- Many electrical devices operate more efficiently (use less power) with reduced voltage

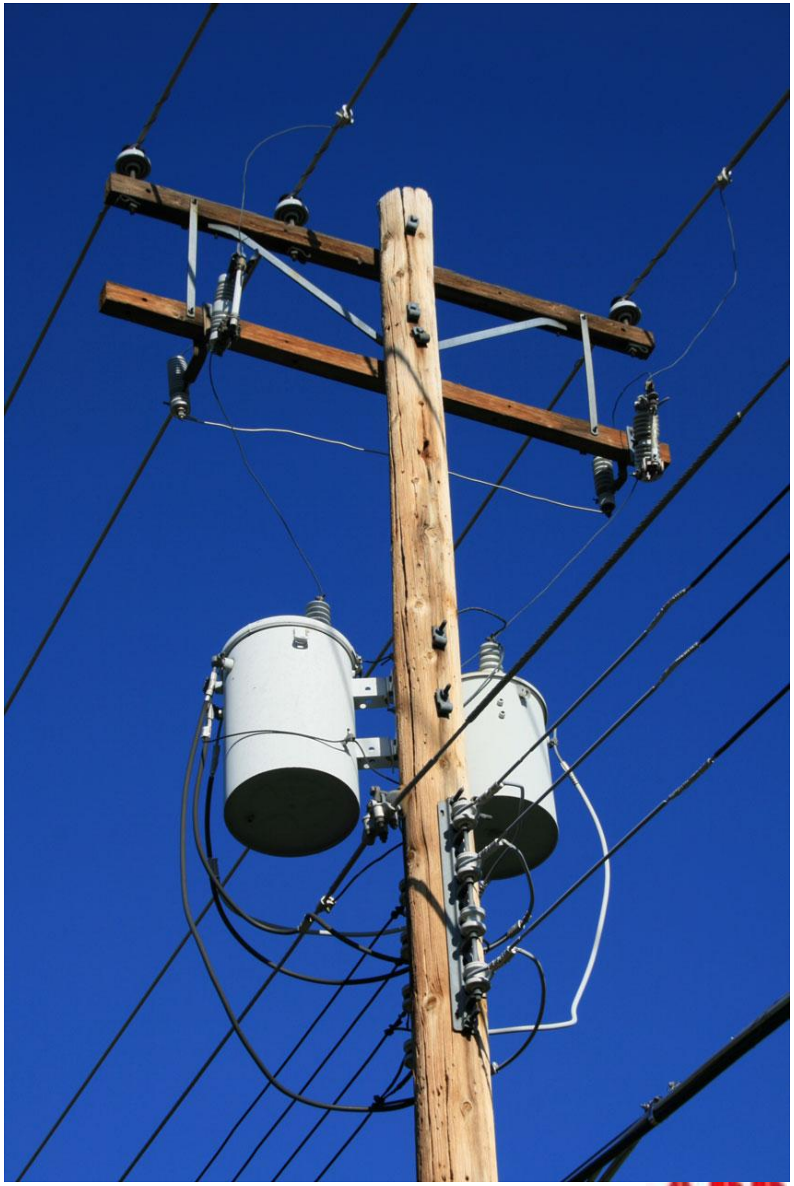
$$P = V^2 \div R$$

"Constant Impedance" Loads

- ***Incandescent Lights***
- ***Resistive Water Heaters***
- ***Electric Stove tops***

Transformer Core (No-Load) Losses

- Losses averaged about 1.4% of total energy consumption and ranged from approximately 0.5% to 3.25%.
- The transformer no-load losses vary as a function of the square of the excitation voltage (V) .



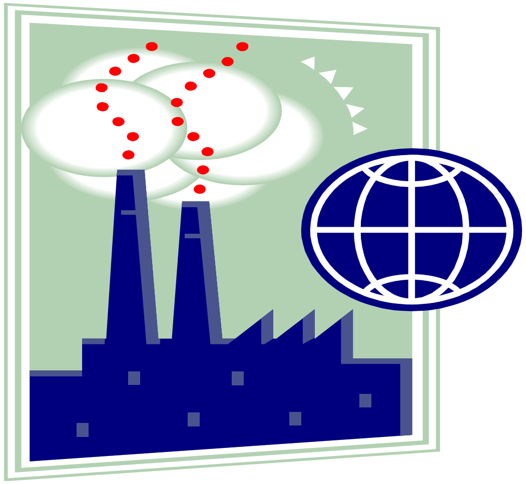
Residential vs Industrial demand reduction

CVR is more effective on residential circuits and during peak loads.

One recent estimate:

1% Volt reduction = 0.76% demand reduction on residential

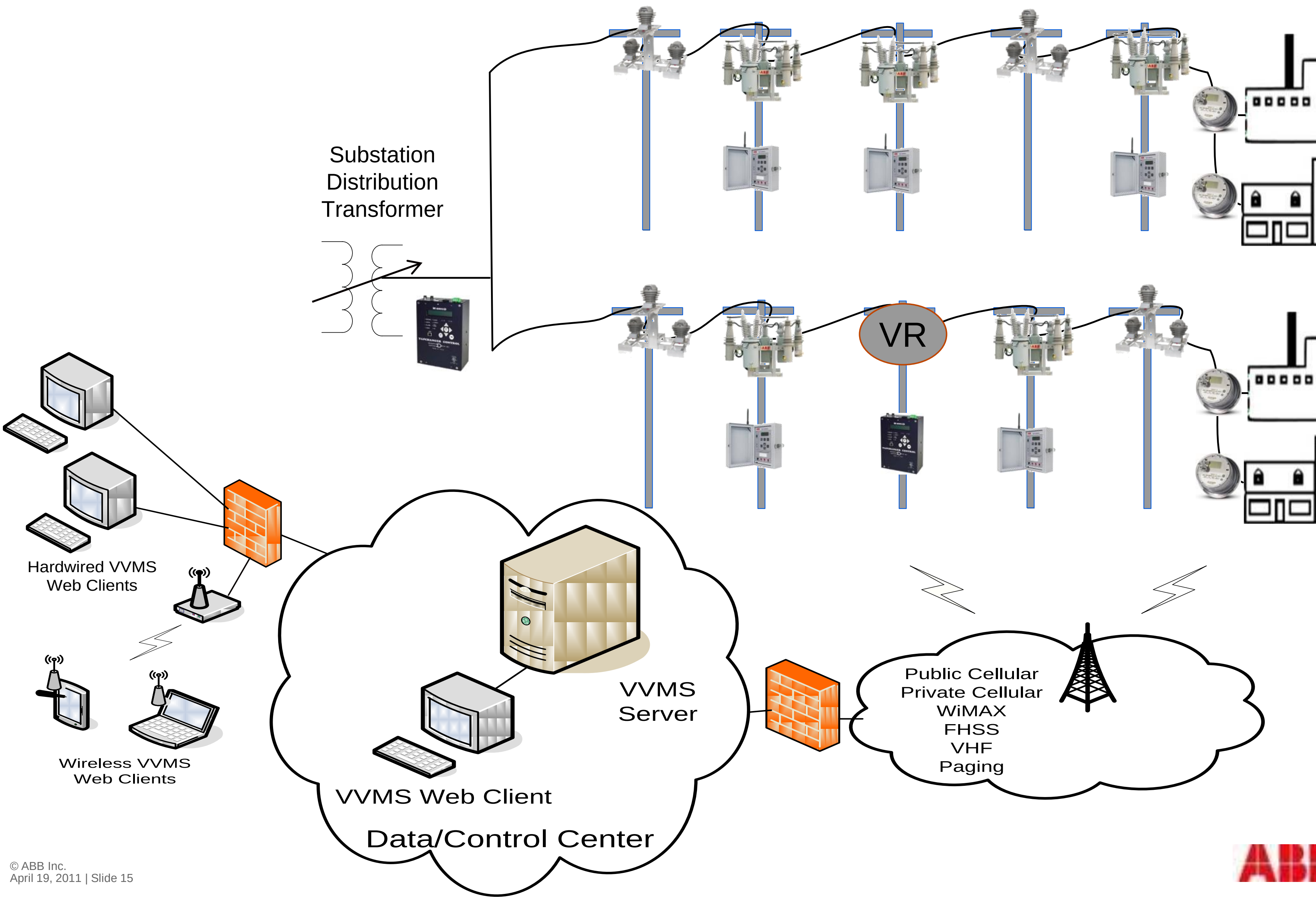
1% Volt reduction = 0.41% demand reduction on industrials



What is a Volt-VAr Management System (VVMS)

- Distribution Automation System to effectively:
  - Manage Distribution Capacitors, Load Tap Changers (LTC) and Voltage Regulators
  - Optimally Reduce VAr losses and improving Power Factor
  - Flatten and maintain Voltage Profiles
  - Reduce demand via Conservation Voltage Reduction (CVR)

Components of a Volt-VAr Management System



VVMS Closed-Loop Volt/VAR Control Algorithm

1. Collect Real-Time Load Data and Device Data
2. Evaluate Voltages with respect to control objectives.
3. Evaluate Load (PF, VARs) with respect to control objectives
4. Determine and prioritize control opportunities.
5. Exclude inhibited (unavailable) devices
6. Calculate the best-available compensating device per control domain.
7. Command device via remote communications link.
8. Confirm operation of 2-way remote device by state feedback
9. Confirm capacitor operation by VAr change at most sensitive control domain (cap, feeder, transformer).
10. Confirm LTC/Regulator operation by Volt change at most sensitive control domain (AMI meter, cap, feeder, transformer).
11. Record results in central database for reporting via web GUI
12. Repeat process continually to improve on circuit efficiency in real time.

Key Benefits of a Volt-VAr Management System

- **VAr Loss Reduction**
- Maintaining Voltage Profile
- Conservation Voltage Reduction
- Additional Key Benefits
  - Failure Detection
  - Performance Analysis

VAr Losses can be Minimized!!!!

- ***Install capacitors*** *as close to source of Vars. Therefore on feeders, rather than at substations.*

  Station capacitors do not reduce circuit VARs.

- ***Install capacitor switches and one-way or two way communicating controllers*** *Utilize existing communication infrastructure, install new network (ie FHSS), use public cellular or other technology*

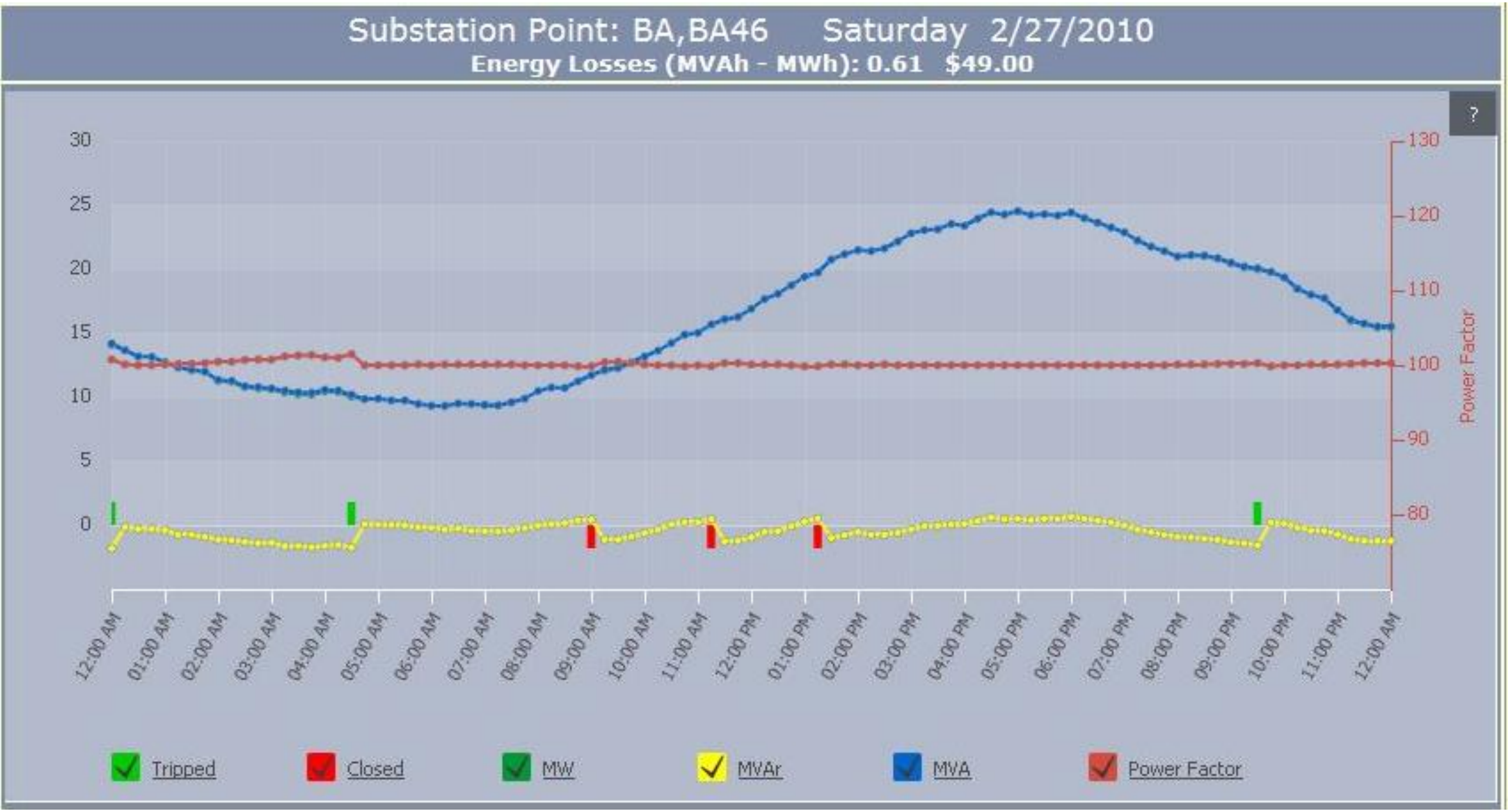
- ***Install a Centralized Volt-Var Mananagement Software (VVMS)*** *which applies intelligent closed-loop volt-var control algorithm*

- ***Maintain capacitors vigorously*** *by repairing failed fuses, switches, controllers, and capacitors as soon as possible.*

- ***Review VAr reduction performance*** *circuit by circuit, regularly with VAr performance management software.*

- ***Add and relocate capacitors*** *for maximum effectiveness based on circuit loads and capacitors in use at system peak.*

Automated control of capacitors for Var Loss Reduction



Key Benefits of a Volt-VAr Management System

- VAr Loss Reduction
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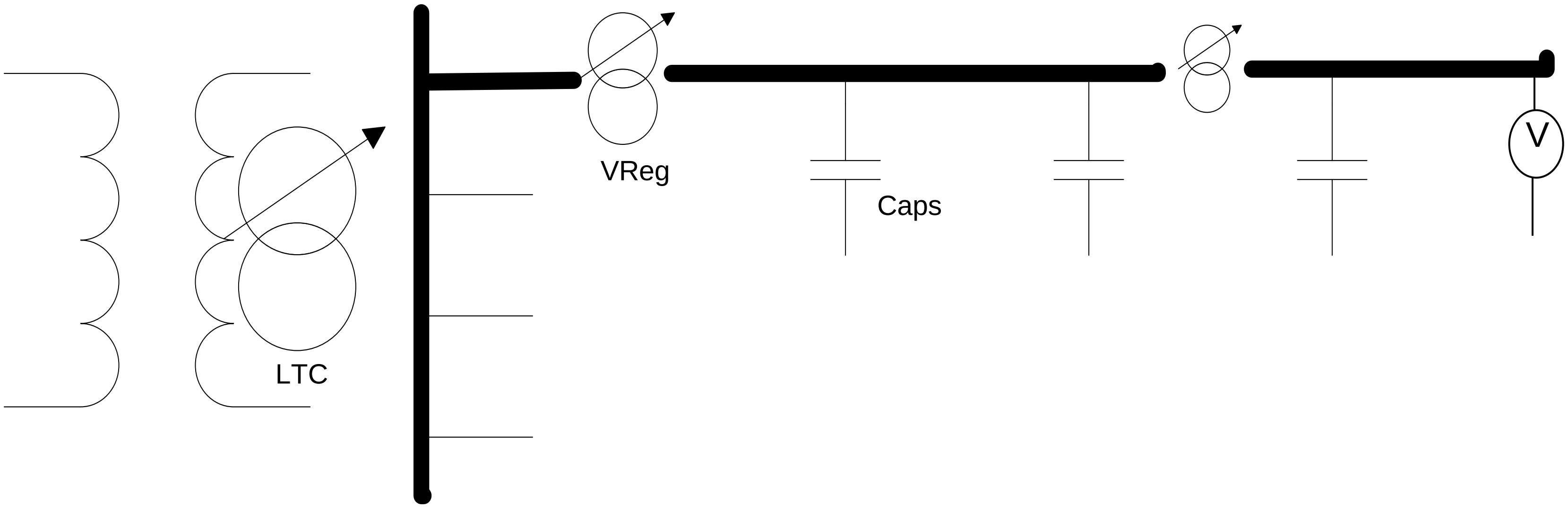
VVMS… Manages voltages while reducing VArs

Automatic control of LTC's, capacitors, and line voltage regulators.



Monitors and regulates consumer voltage with reference to….

Voltage at customer meters

Voltage at capacitor sites

Voltage at additional metering points

Operates LTC stepping and capacitor switching to maintain voltage profile and voltage quality while reducing VArs.

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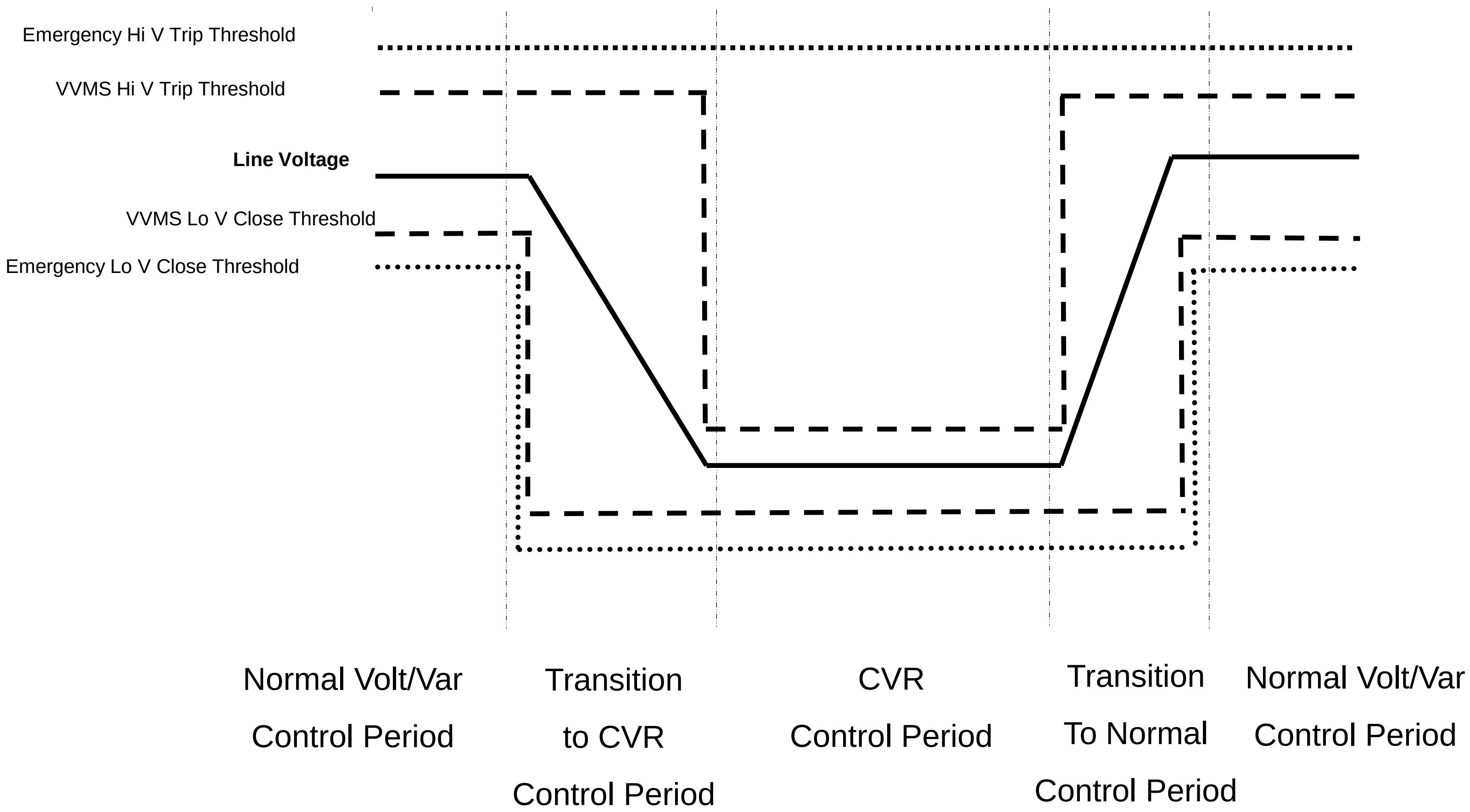
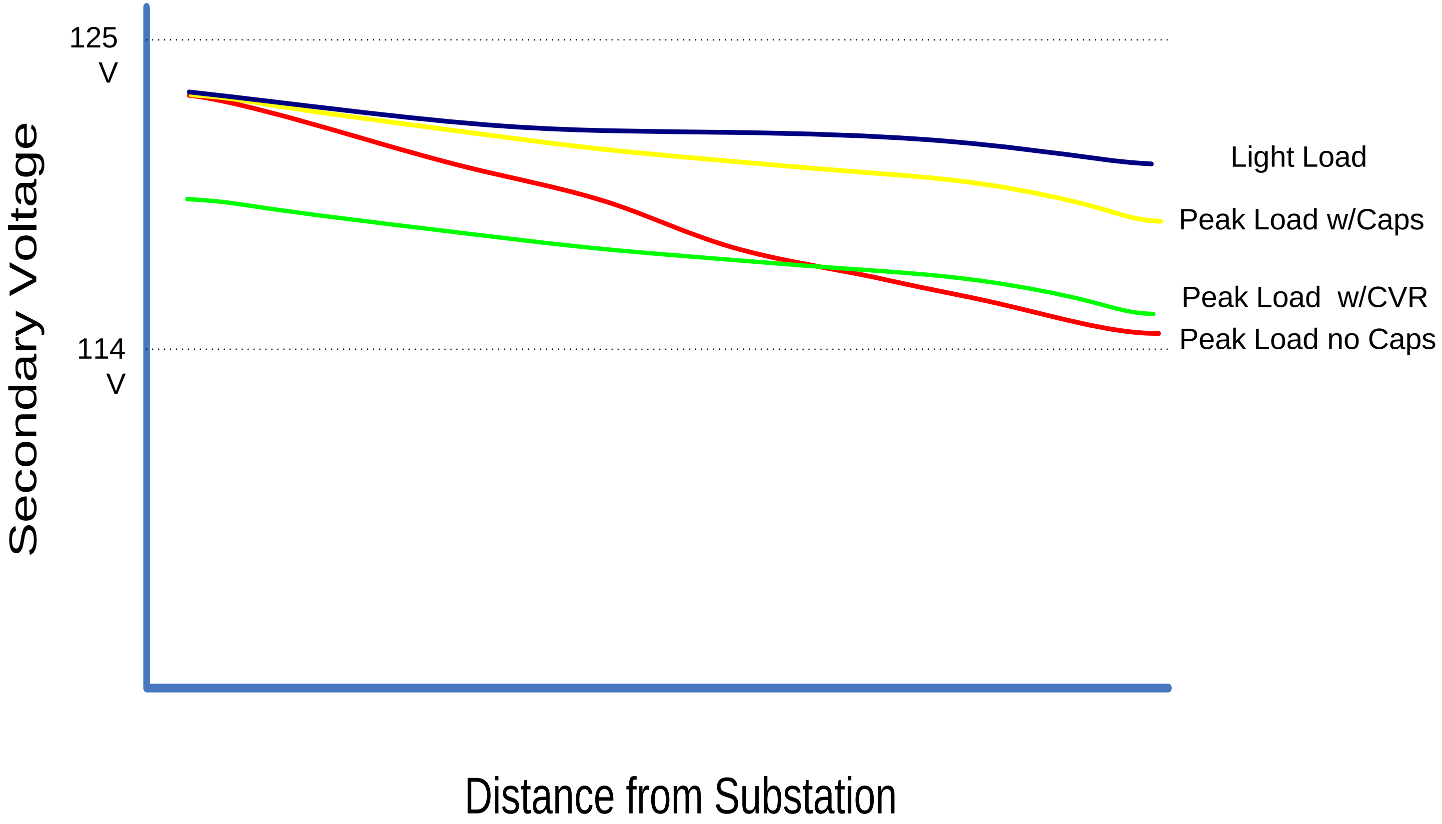
VVMS with CVR (conservation voltage reduction)



Effects of VAr Minimization and CVR on Voltage Profile



Key Benefits of a Volt-VAr Management System

- VAr Loss Reduction
- Maintaining Voltage Profile
- Conservation Voltage Reduction
- Additional Key Benefits
  - Failure Detection
  - Performance Analysis

Two-Way Cap Controllers promote Failure Detection

- Measured Voltage enables flatter voltage profiles and facilitates features such as Conservation Voltage Reduction.
- Enables cap level Var measurements promoting a more efficient Var algorithm that chooses capacitor nearest to the VAr source

- Provides positive confirmation of Cap State to validate operation. Resynchronization is immediate as opposed to waiting for a refresh cycle.
- Monitoring of Neutral Current promotes phase fault detection.
- Local inhibits can be recognized by VVMS and therefore the inhibited cap can be bypassed in favor of another available cap. This also reduces erroneous failure indications.
- Helps isolate failure cause such as communication failures

- Reduces cost of periodic auditing of capacitors

VAr Loss Performance Monitoring Tool for measuring efficiency

- Benefits
  - Prioritize “VAr challenged” circuits.
  - Identify problem causes.
    - Insufficient capacitor assets
    - Ineffective switching strategies
    - Damaged caps, fuses or switching apparatus
  - Establish consistent baseline for….
    - Evaluating corrective actions
    - Maintaining long-term high performance.
  - Reduce capacitor auditing costs

ABB VAr Loss Analysis (Example 1)

Pilot study….Analysis of 12 Feeder Circuits

VAr losses reported 3% of total energy purchased

Feeder	KWh	KVAh	Power Factor	KVAh Loss	$$$ Loss
Lisbon	20,276,616	21,456,736	94.5%	1,180,120	$94,410
Melvin	17,874,904	18,955,359	94.3%	1,080,455	$86,436
Norling	31,152,579	32,198,148	96.8%	1,045,569	$83,646
Pasteur	19,710,907	20,618,104	95.6%	907,197	$72,576
Park	24,117,146	24,934,622	96.7%	817,476	$65,398
Biswas	18,811,130	19,507,089	96.4%	695,959	$55,677
Morey	17,722,799	18,270,927	97.0%	548,128	$43,850
Banton	19,112,686	19,564,216	97.7%	451,530	$36,122
Stratton	8,699,167	9,077,135	95.8%	377,968	$30,237
Zavalick	7,251,236	7,506,912	96.6%	255,676	$20,454
Main St	26,487,306	26,700,913	99.2%	213,607	$17,089
Franklin	20,358,342	20,481,229	99.4%	122,887	$9,831
Total Annual	**231,574,817**	**239,271,390**	**96.4%**	**7,696,573**	**$615,726**

12 circuit energy cost = 239,000,000 * $0.08/kwh = $19.0 Million

Power factor losses = 7,696,000 * $0.08/kwh = $0.6 Million

ABB VAr Loss Analysis (Example 2)

Large utility with <u>hundreds of Feeder</u> Circuits

VAr losses 4% of total energy cost

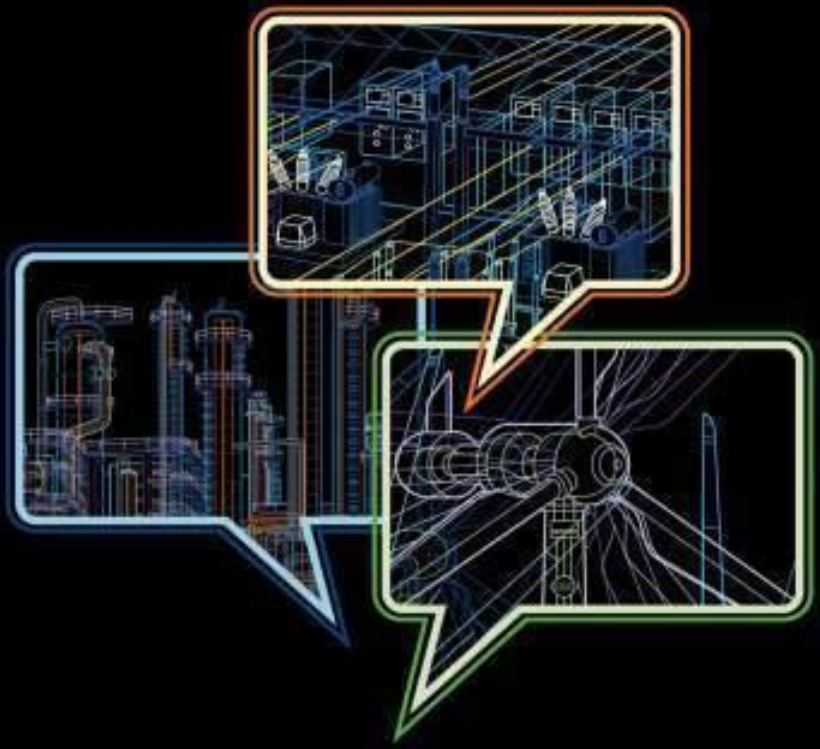
YY MM	KWh	KVAh	KVAh Loss	$ Loss
08 12	71,115,991	77,585,302	6,469,303	$258,761
09 01	274,155,424	294,748,092	20,592,623	$823,649
09 02	306,746,953	331,288,714	24,541,720	$981,613
09 03	314,118,262	344,839,360	30,721,054	$1,228,791
09 04	291,324,566	321,479,105	30,154,493	$1,206,125
09 05	294,352,070	325,601,407	31,249,287	$1,249,911
09 06	328,886,245	356,807,280	27,920,992	$1,116,786
09 07	135,074,664	143,601,082	8,526,403	$341,039
09 08	398,113,124	424,636,627	26,523,448	$1,060,880
09 09	329,520,473	357,220,962	27,700,444	$1,107,955
09 10	310,841,095	342,716,721	31,875,586	$1,274,963
09 11	282,268,152	311,576,180	29,307,986	$1,172,262
2009 Total	**3,336,517,019**	**3,632,100,832**	**295,583,339**	**$11,822,735**

Total energy purchased = $290 million/year

VAr Losses = **<u>$12 million/year</u>**

Major Factors Driving Volt-VAr technology

- $$$$$ Savings
  - Energy Savings
  - Deferred or Avoided Capacity Buildout
  - Eliminate Capacitor Audits
- Improve Grid Reliability
- Reduce Carbon Emissions
- DOE Stimulus funding available



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Feeder monitoring

Increasing efficiency through voltage regulation

Feeder monitoring
The technical side

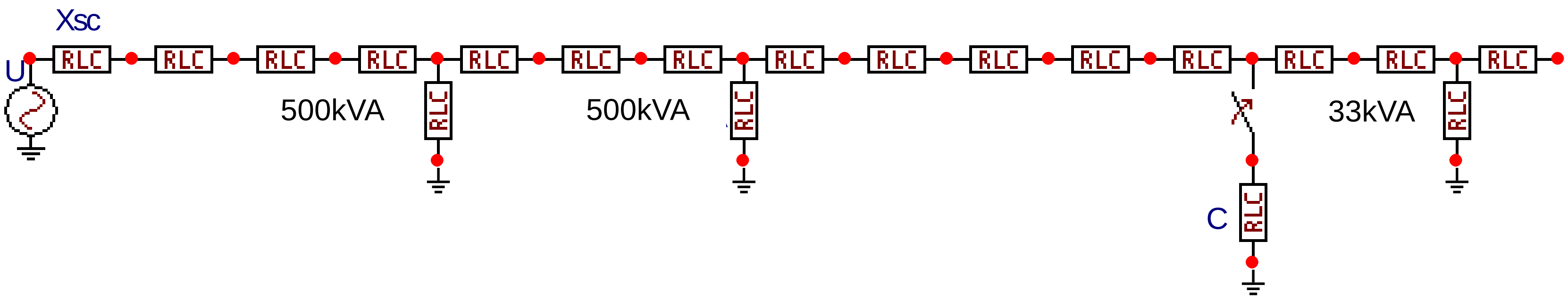
Calculations of a distribution feeder with different loads, configurations, and capacitive compensation.

Output results:

- Voltage profile along the feeder and reactive power balance (VVO)
- Power loss in feeder
- CVR - Conservation Voltage Reduction or Voltage Regulation

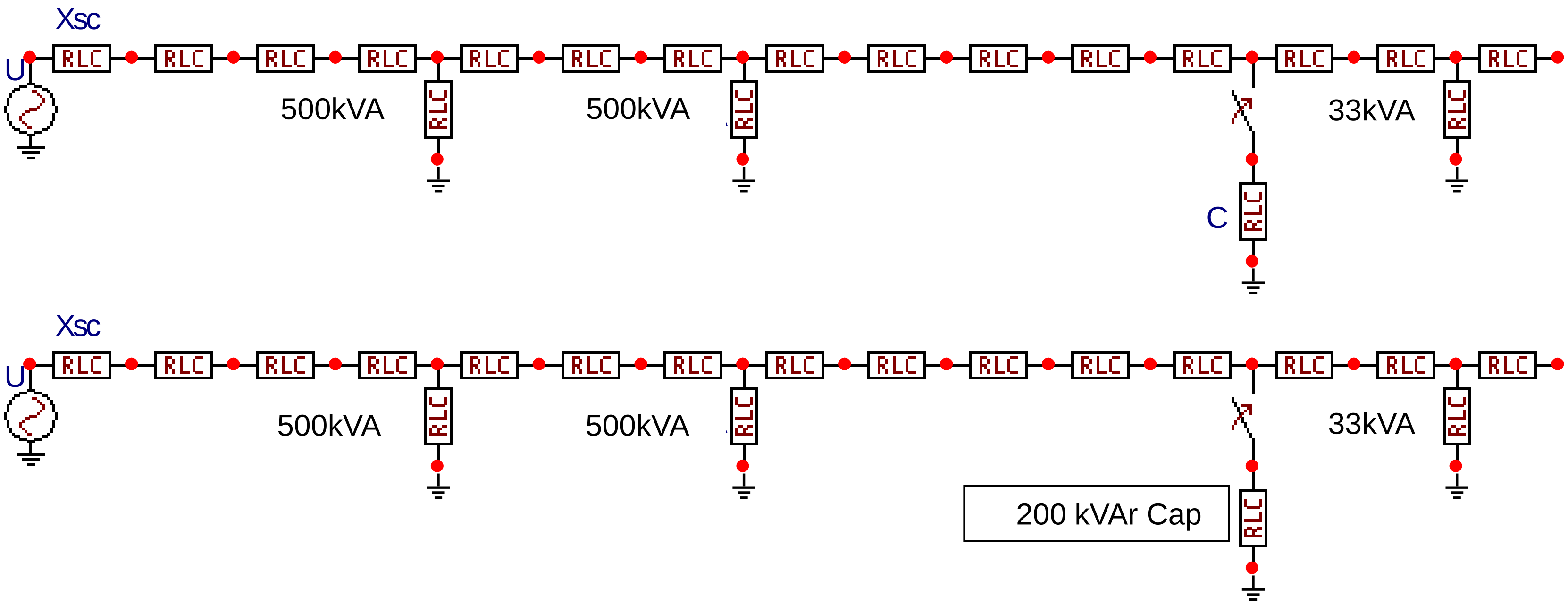
Explaining the value proposition
The technical side

- Radial feeder single source
- 15kV system, 20 kA SCC
- 3 lumped loads – varying from 0 to 1000 kVA and pf from 0.8-1.0 (these are nominal loads)

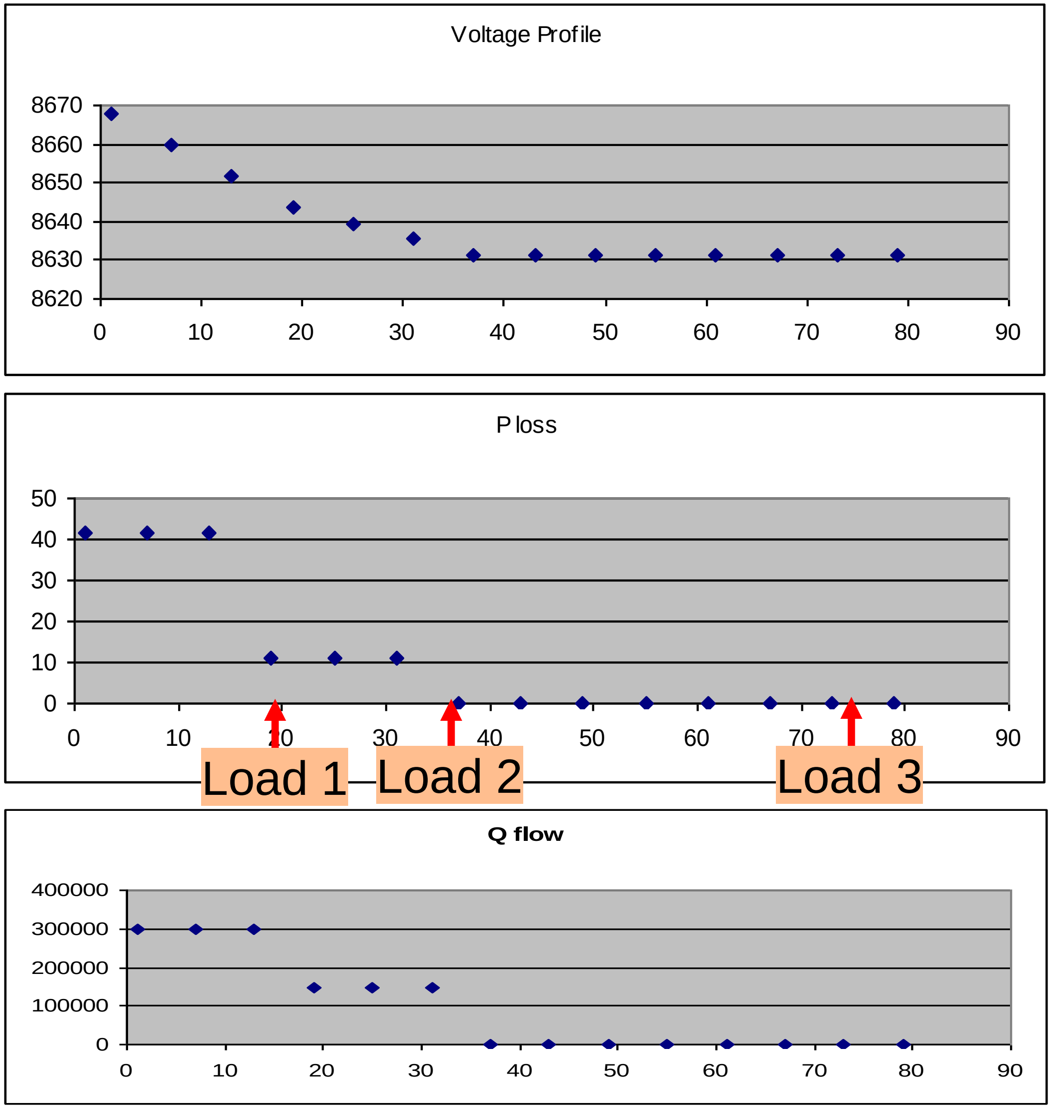


One capacitor switchable located about 80% down the line varying from 200 kvar to 800 kvar

Sample feeder line
Light load, no capacitor; Light load, 200kVAr capacitor



Data results
Light load; no capacitor



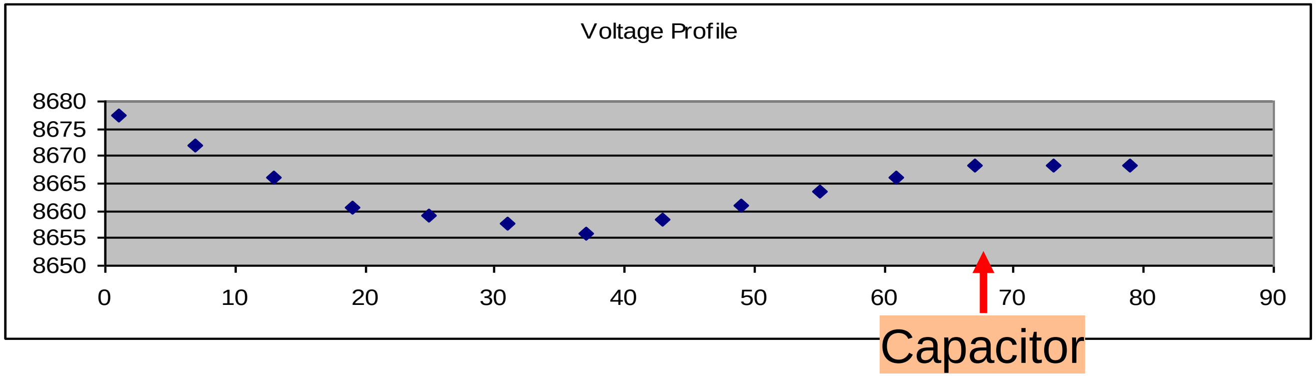
V reg = 0.42%
P loss = 314 W
P tot flow = 0.824 kW
Q tot flow = 0.602 Mvar

Data results
Light load; 200 kVAr capacitor

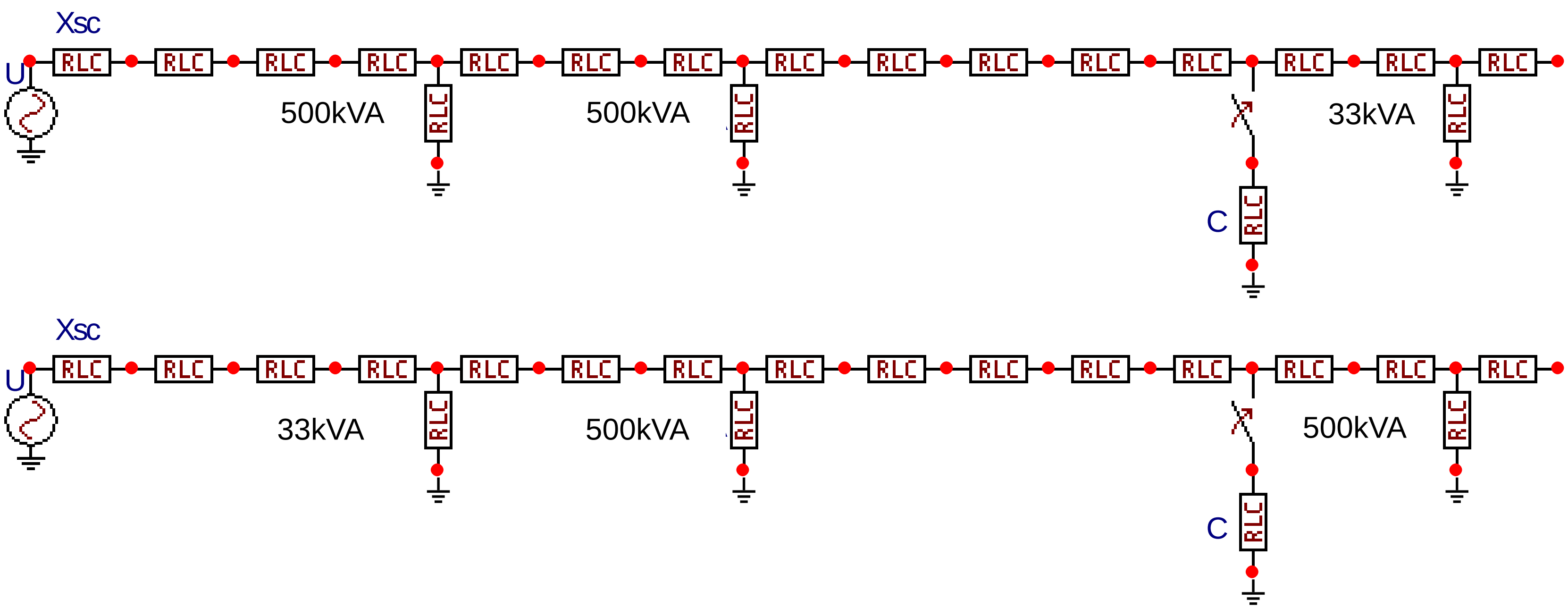
The same total load on the feeder but added 200 kvar capacitor
Ex 5 compared to Ex 4

V Reg	P Loss	Q Flow
40.5%	15.3%	32.6%

Losses improved (dropped) by 15% when switching on the cap
Reactive power requirement dropped by 33%
Voltage fell in the middle of the feeder



Sample feeder line
Heavy front load vs heavy back load

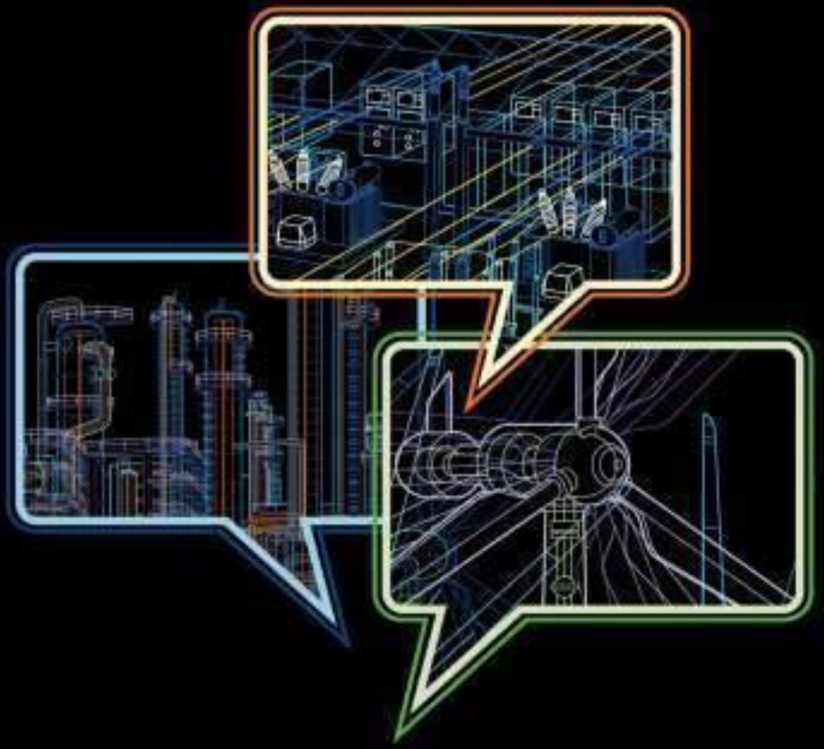


Data results
Different load distribution

- The same total load on the feeder but differently distributed

V Reg	P Loss	Q Flow
-111.9%	-96.2%	-0.3%

- Voltage regulation worsened when load is more remote
- Losses almost doubled (- 96%) when load is more remote
- Reactive requirement almost the same
- Need to know the voltage(s) on the feeder to determine regulation and losses



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Feeder monitoring
Conclusions

Conclusion
From model to real world

Every load is different

- Loads have an important effect on the distribution feeder performance
- Loads are complex and variable
  - Change dynamically 24/7
  - Load characteristics (pf, harmonics, kZ, kP, kI, etc.)
  - Grow/shrink over time
  - From feeder to feeder
  - With weather (temperature, …)

Conclusion
From model to real world

To optimize a distribution system performance means:

- To keep the voltage regulation within the limits
- To minimize the reactive power requirement
- To reduce losses

To fully optimize a distribution system performance one needs to measure:

- Voltage along the feeder (regulation and voltage profile)
- Reactive power flow
- Power losses of the feeders

Conclusion
From model to real world

Rules of Thumb for selecting and locating monitoring points:

You should consider feeder monitoring for:

- Feeders with significantly varying loads
- Feeders with mixed load types (kP, kZ, etc.)
- Feeders where aggregate data from Smart Meters is not available or does not add up
- Feeders where conservation voltage reduction (CVR) is to be used
- Distribution systems where performance optimization is important

Conclusions
Current and voltage sensing

SCC-125 split-core combo

Revenue class accuracy

Ease of installation

Any phase control power

HCEP

- Line post sensor
  - 1% accuracy
  - Ease of installation
  - CEP