Cost Effectiveness of Distribution Automation

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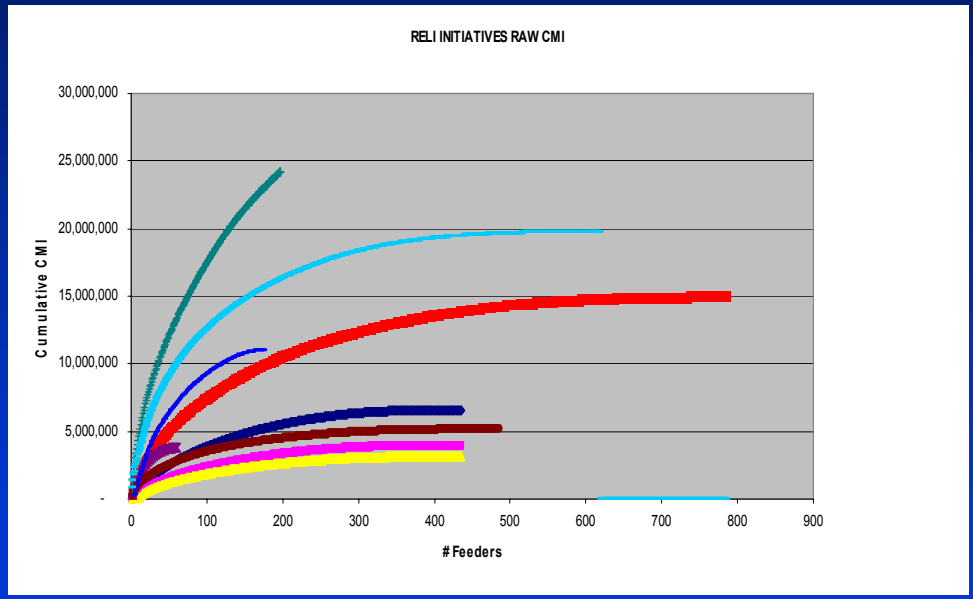
Reliability Improvement Options
Two General Categories

- Fault Prevention
- Fault Mitigation

Fault Prevention

- Lightning protection
- Tree Trimming
- Animal Protection
- Others
- Can be targeted in an integrated optimized blend of programs



Fault Mitigation

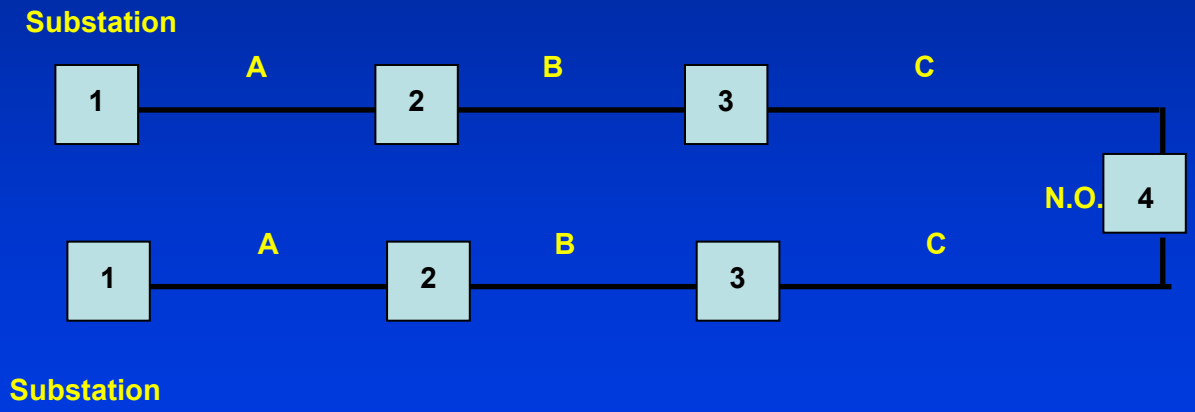
- Fuse Save Overcurrent Protection
  - Prevents temporary branch line faults from becoming sustained interruptions
- Feeder Design Schemes
  - Main Line Reclosers
  - Switches
  - Distributed Automation (DA) or SCADA
  - Switching and Restoration Strategies

Why Automation or SCADA?

- **Improved Reliability**
  - But how much improvement?
  - At what Cost?

Predictive Reliability

- Evaluates the system performance based on system design configuration and historical operating data or assumptions

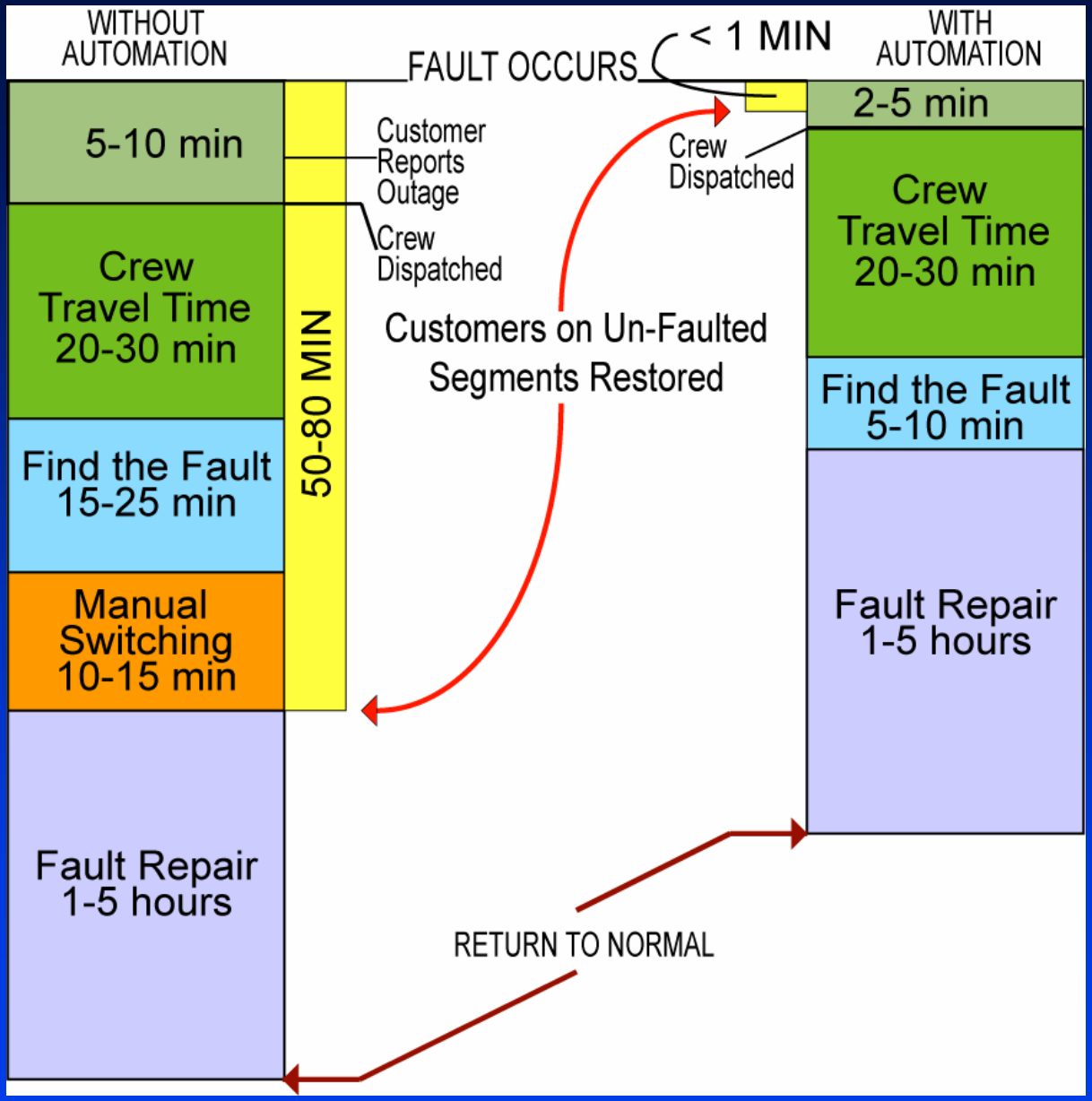


Terms

- SBD = Solid Blade Disconnect Switch
- SCADA = Remote controlled switch – requires human input to change state
- DA = Distributed Automation system with local on site intelligence and communication (Intelliteam II)

Input Parameters

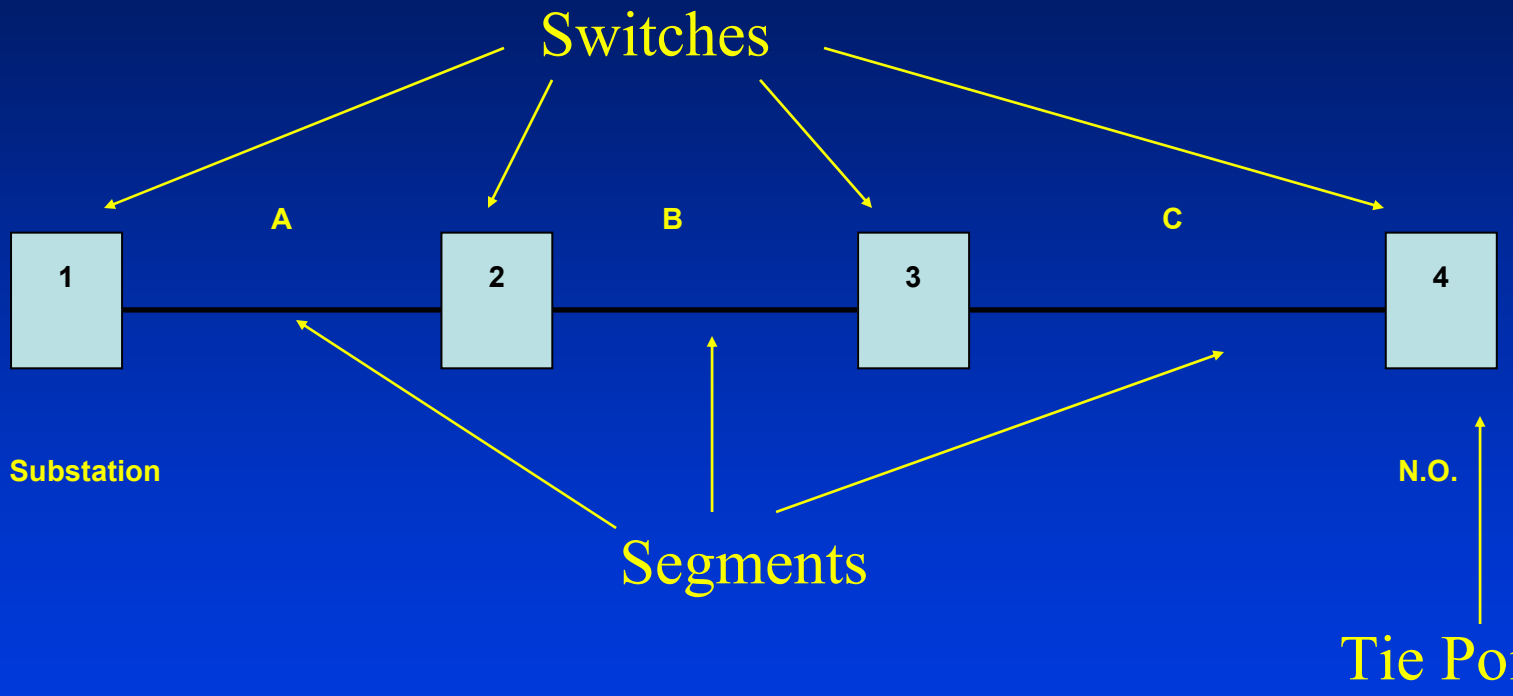
- Frate = annual permanent fault rate (Faults/mile / yr)
- Length = total miles of main line feeder exposure
- Customers = total customers served (includes customers on fused taps)
- MTTS = Mean time to switch (varies by switch type)
- MTTR = Mean time to repair and restore faulted segment
- Segment = section of line between switching devices


WITHOUT AUTOMATION
FAULT OCCURS
< 1 MIN
WITH AUTOMATION
5-10 min
Customer Reports Outage
Crew Dispatched
Crew Travel Time 20-30 min
50-80 MIN
Customers on Un-Faulted Segments Restored
Find the Fault 15-25 min
Manual Switching 10-15 min
Fault Repair 1-5 hours
RETURN TO NORMAL
2-5 min
Crew Dispatched
Crew Travel Time 20-30 min
Find the Fault 5-10 min
Fault Repair 1-5 hours

Reliability Measures

- IEEE 1366 – Standard for Reliability Reporting
- SAIDI = CMI/C
- SAIFI = CI/C
- CAIDI = CMI/CI
- CMI = Customer minutes of interruption
- Outage = interruption > = 5 minutes
- Momentary = interruption < 5 minutes
  - Measured by MAIFI = Mi*Ci / C

Feeder Design Scheme



Switches can be many types:

SBD – RCL - SCADA - DA

Feeder Design Schemes

- SBD Radial
- RCL Radial
- SBD Loop
- RCL Loop
- SCADA RCL LOOP
- SCADA SBD LOOP
- Distributed Automation Loop (DA Loop)

Feeder Design Schemes – Loop SBD

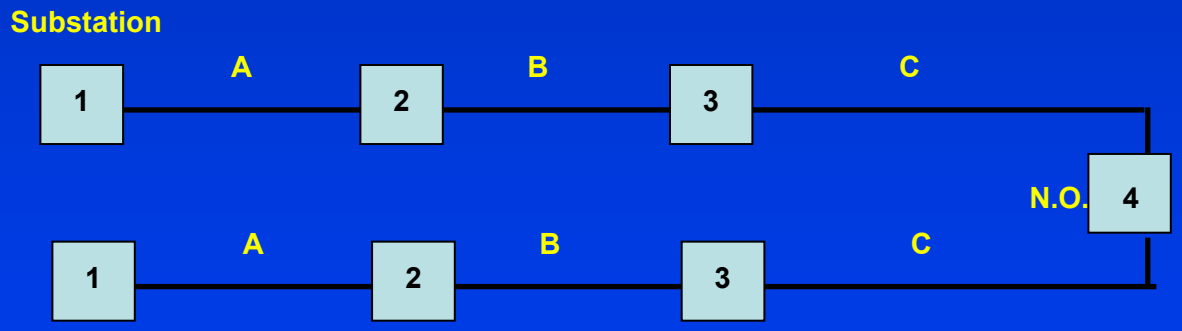
- All Switches are SBD
- Require local manual operation
- Non Fault interrupt
- Provide for manual segmentation after fault
- May or may not have alternate feeder tie(s)
- All segments experience initial outage
- Faulted segment outage duration = MTTR
- Other segment outage durations = MTTS

Feeder Design Schemes – Loop RCL

- Provide Switching capabilities – fault and load interrupt rated
- Faulted Segment and downstream segments see initial outage
- Faulted segment outage duration = MTTR
- Downstream outage segment duration = MTTS
- Upstream segments see no outage
- Provide automatic isolation for downline faults
- Requires local manual operation to restore service

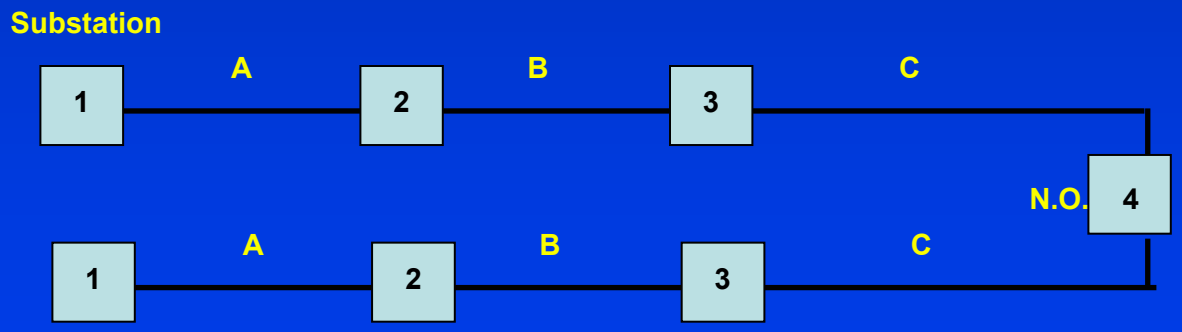
Feeder Design Schemes – SCADA RCL

- Provide Switching and fault isolation capabilities
  - Fault interrupt rated with overcurrent protection
  - only downstream customers experience outage
- Provide remote fault indication and switching control
- Requires dispatcher operation to restore service
- Faulted segment duration = MTTR
- Other segment durations = MTTS



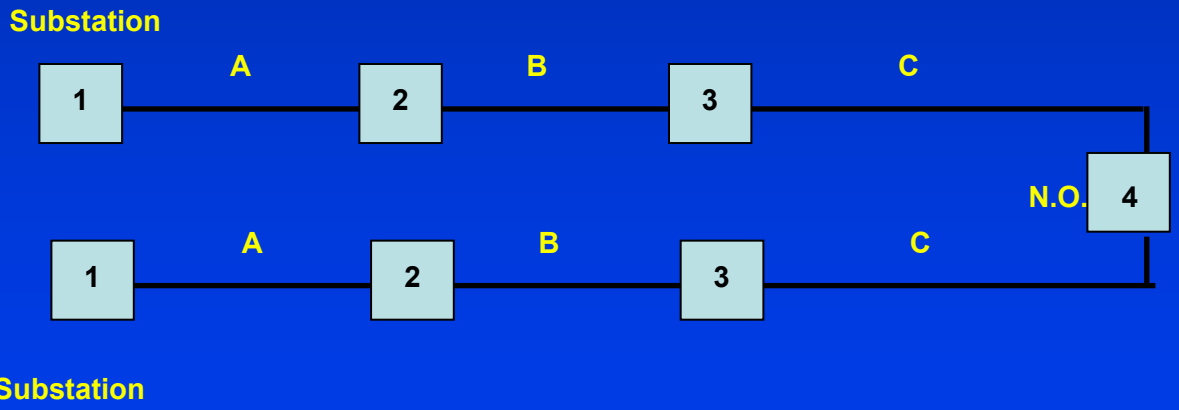
Feeder Design Schemes – SCADA SBD

- Provide Switching capabilities
  - Usually fault close but only load interrupt rated
  - All customers experience initial outage
- Provide remote fault indication and switching control
- Requires dispatcher operation to restore service
- Faulted segment duration = MTTR
- Other segment durations = MTTS



Feeder Design Schemes – Loop DA

- Uses Distributed Intelligence and Communication
- Provides automatic faulted segment isolation
- Provides automatic restoration to loads via feeder ties (<5 min) = No “outage” per IEEE 1366
- Only the faulted segment experiences an outage
- Can automatically check for and prevent overloads

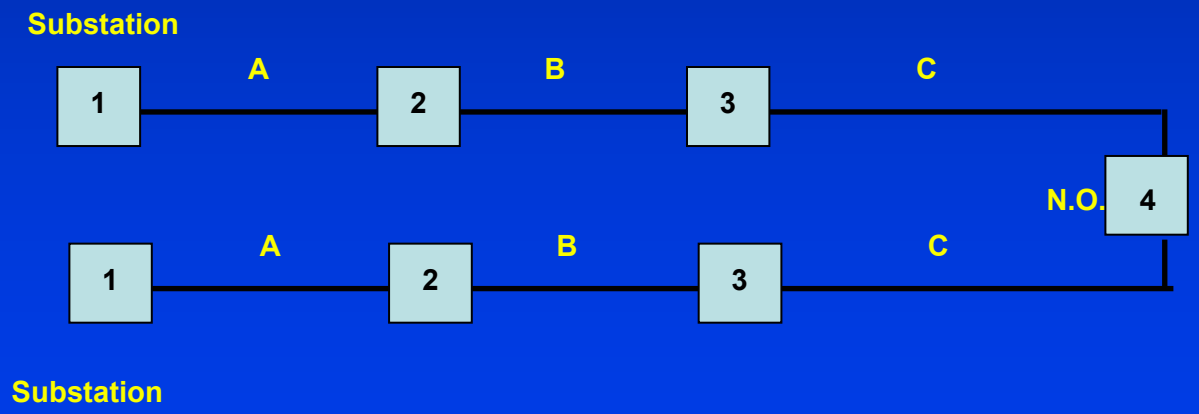


Predicted Reliability Assumptions

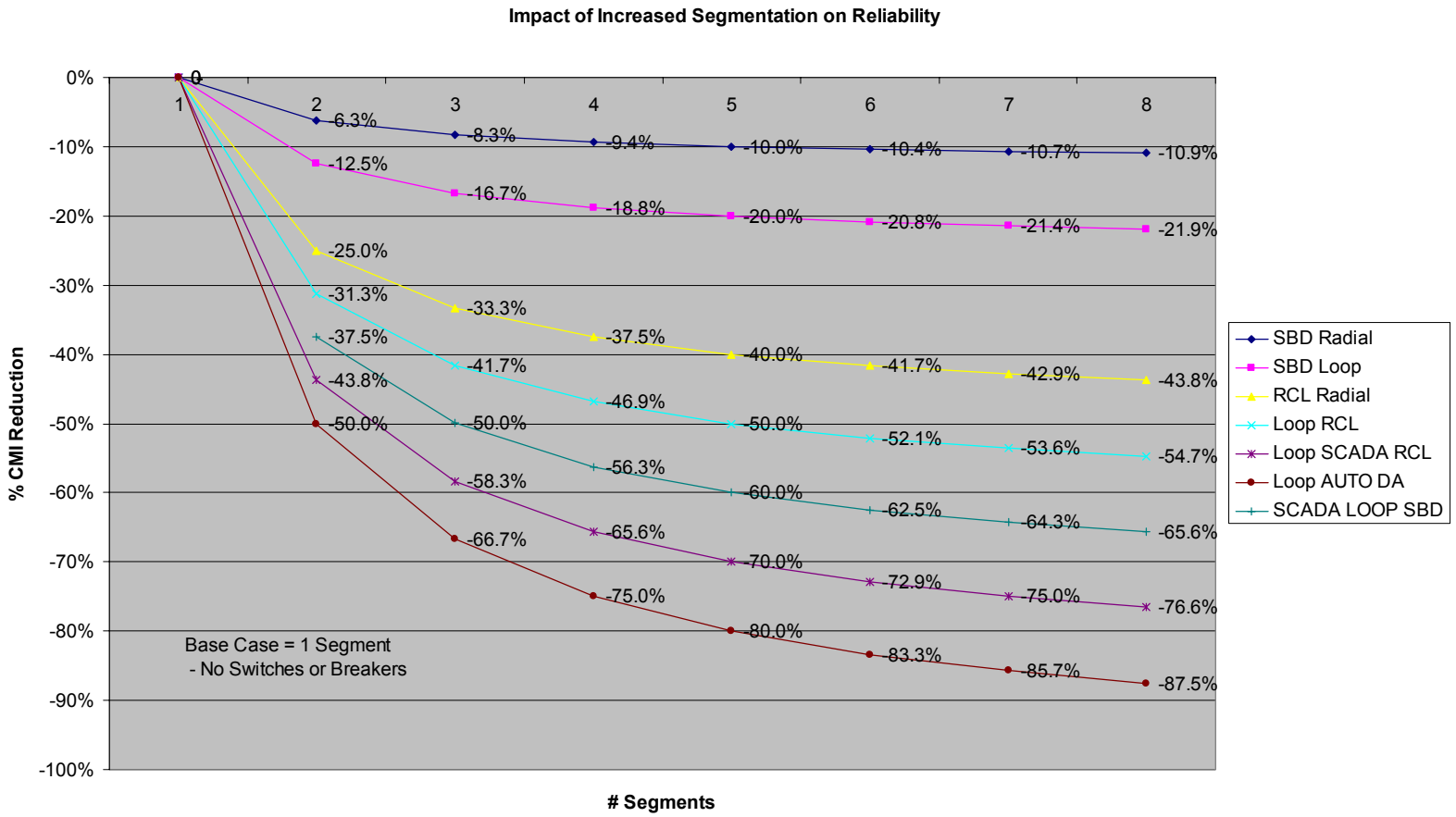
- Uniform Fault Rates = Frate
- Uniform Customer distribution (Customers/mile)
- Adequate capacity for transfer of load
- All segments are linear – only one alternate tie

Segmentation Advantages

- Breaks Feeder into smaller pieces
  - Less customers interrupted per segment
  - Less miles = lower fault exposure = fewer outages to a particular segment
- Measure of Segmentation = Customers*Miles

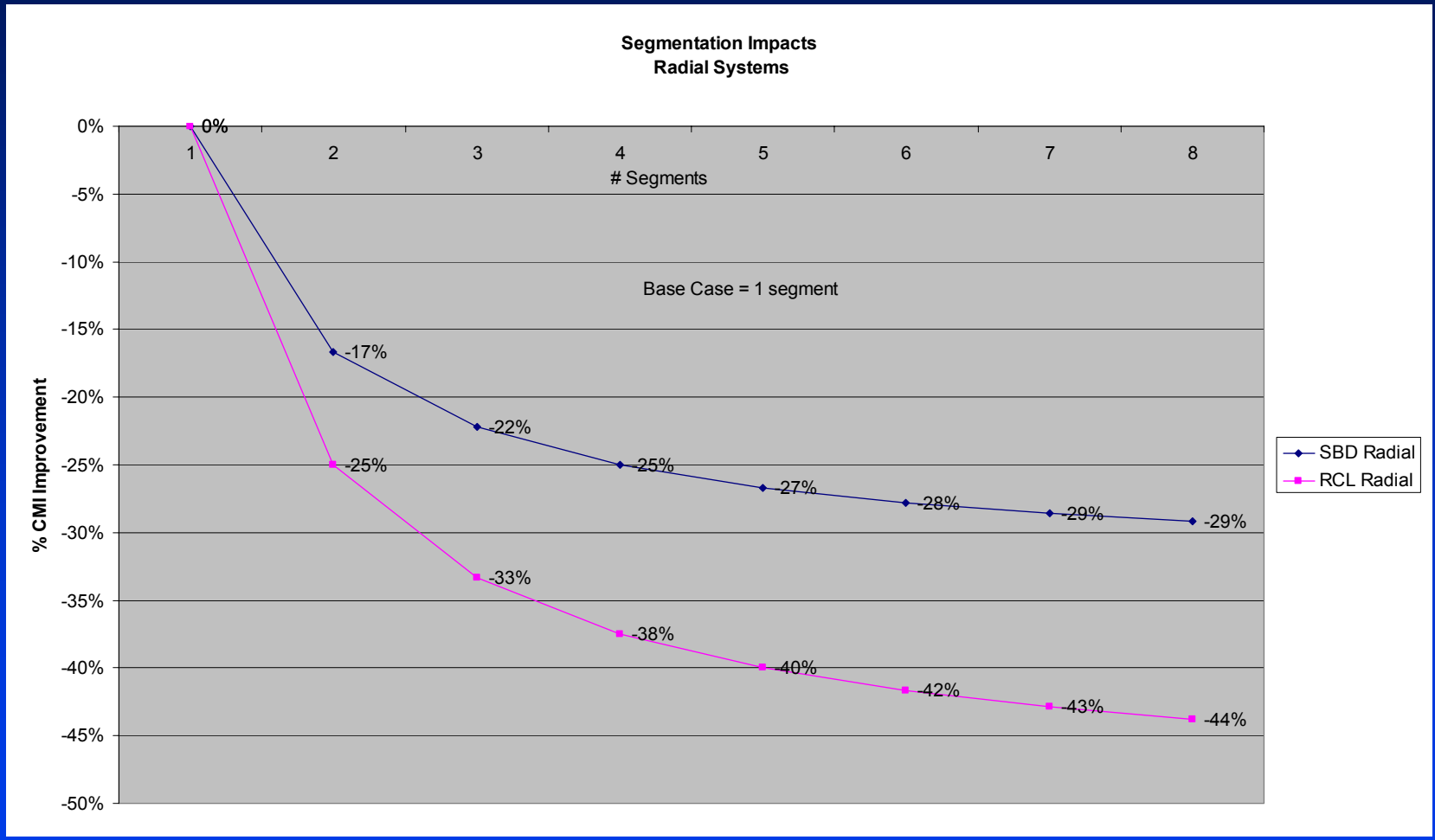


Segmentation Advantages



Radial Systems – Segmentation Benefits

No Alternate Feeder Ties

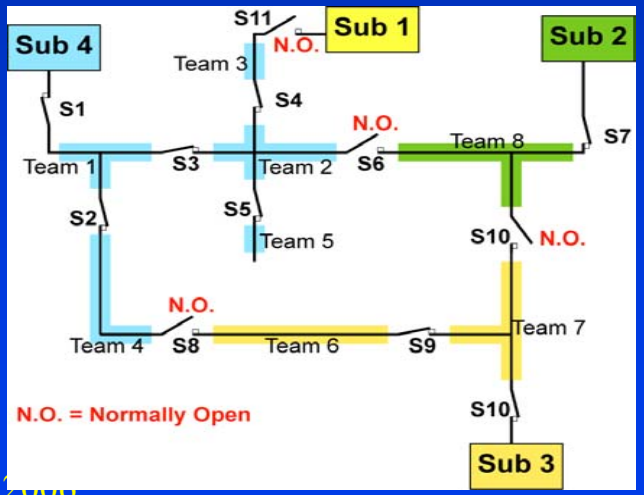


Non-Uniform Segmentation Drivers

- Non – Uniform Fault rates
  - Isolate the bad segments!
- Sensitive or Critical Customers
- Geography
  - Major taps or significant splits
- Loading
  - Concentrated or large loads

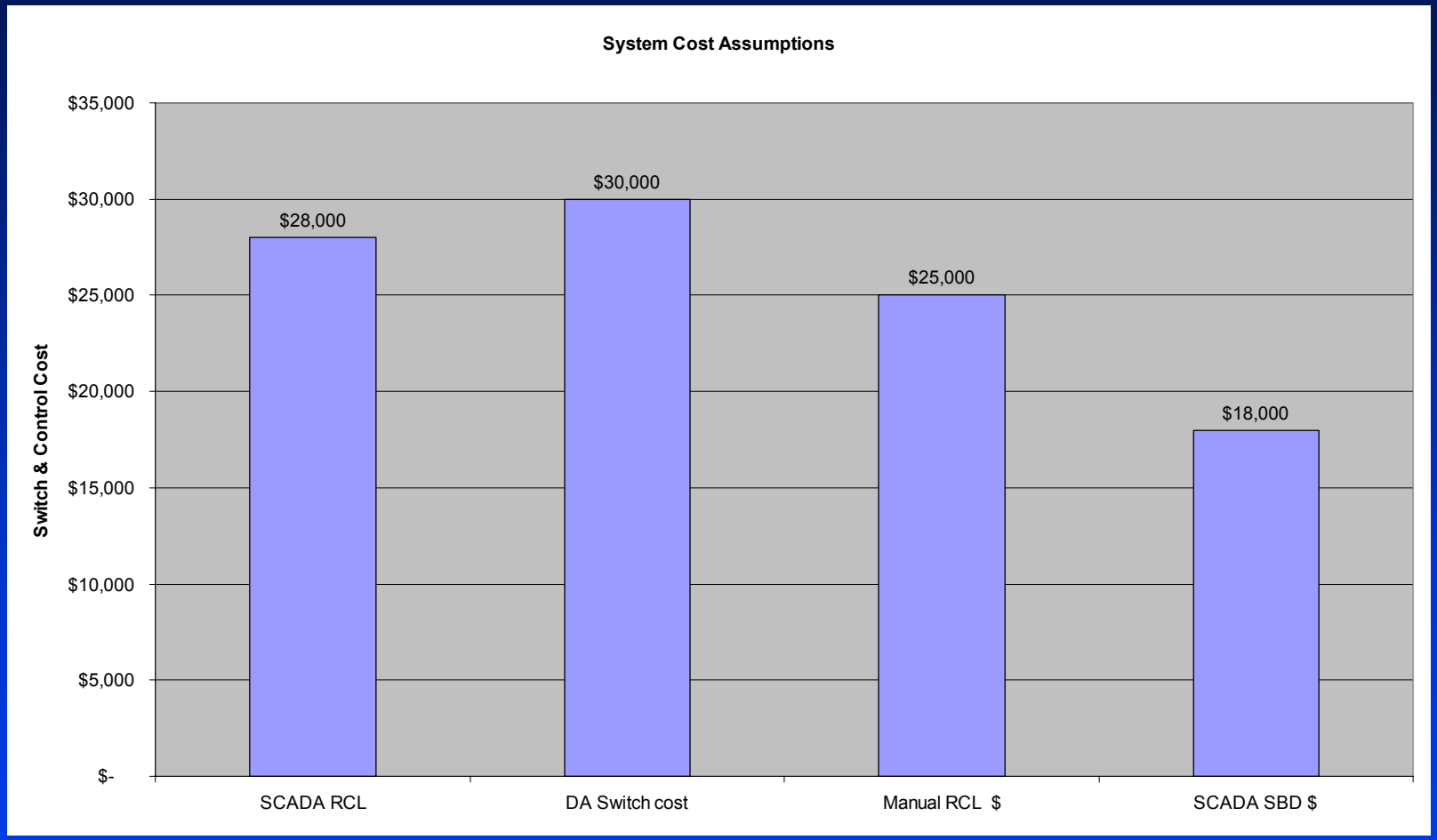
Impact of T-Sections

- No impact on predicted reliability calculations
- Impacts economics
  - 2 or 3 switches added for segment instead of 1
- May be required to meet feeder capacity limits



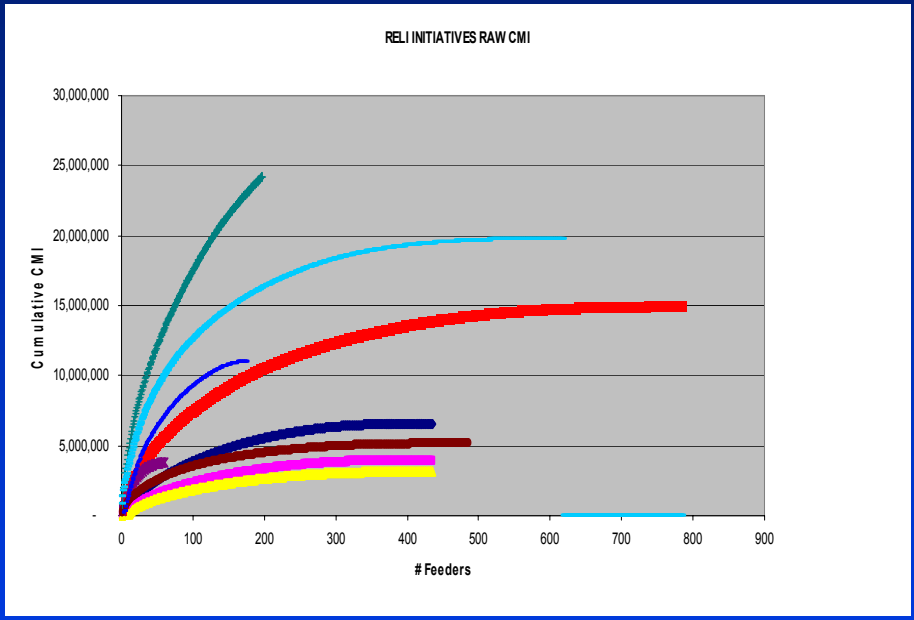
This scheme is not linear. It uses T sections with multiple feeder ties. This increases the number of switches and cost – no change in predicted reliability for Single Contingency

Economics of Reliability – cost assumptions



Economics of Reliability

- Typical overall optimized reliability improvement program cost ranges – all programs
  - $0.67 per CMI
    - "low hanging fruit"
  - $1.67 per CMI
    - "at end of program"
- Looped DA Costs are typically $0.33 - $0.76 per CMI - depending on segmentation level
- Other variables will impact these costs (MTTS, MTTR, Frate, Cust, Miles, ETC)



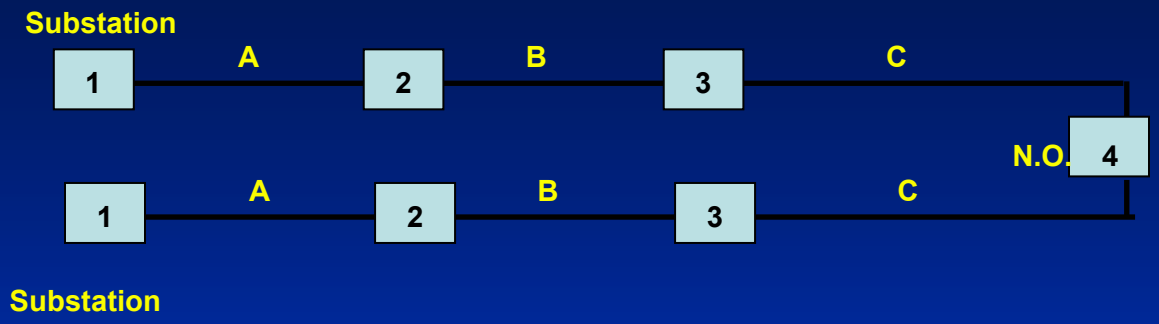
Regulatory Penalties for Poor Reliability

- Penalties = ???
  - $1million per SAIDI over limit

Parameter Sensitivity

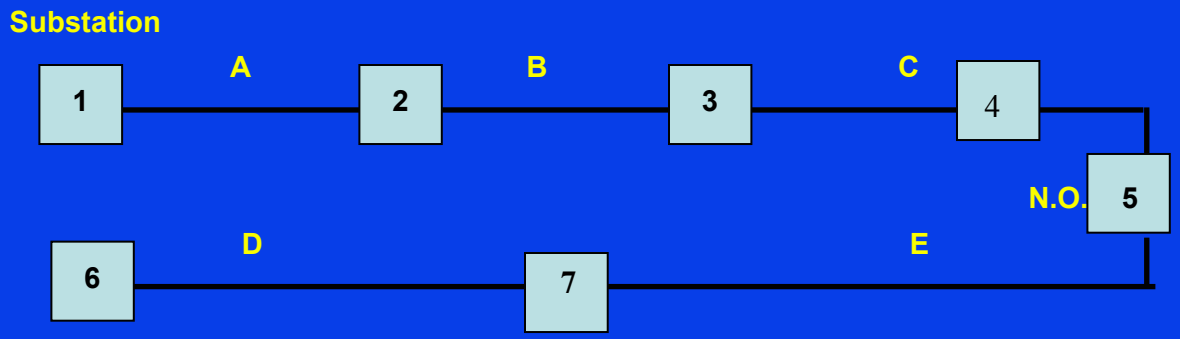
- CMI or SAIDI are sensitive to Frate, Cust, Miles, MTTR, MTTS, # Segments
- % CMI or %SAIDI Changes Are NOT sensitive to Frate, Cust, Miles but Are sensitive to MTTS and MTTR

Example System



MTTR	120
Fault rate	0.2
FDR Miles	10
Cust	2000
Manual Switch Time	90
SCADA Switch Time	30
AUTO Switch Time	0

Loop System Reliability



# SEGMENTS	Substation SBD LOOP	RCL LOOP	SCADA RCL	Loop Auto DA	SCADA SBD	SEG Cust * Miles
		10 Mile Feeder				
2	210	165	135	120	150	10,000
4	195	128	83	60	105	5,000
		5 MILE Feeder				
2	120	105	97	90	135	5,000
4	90	67	56	45	83	2,500

System SAIDI Results

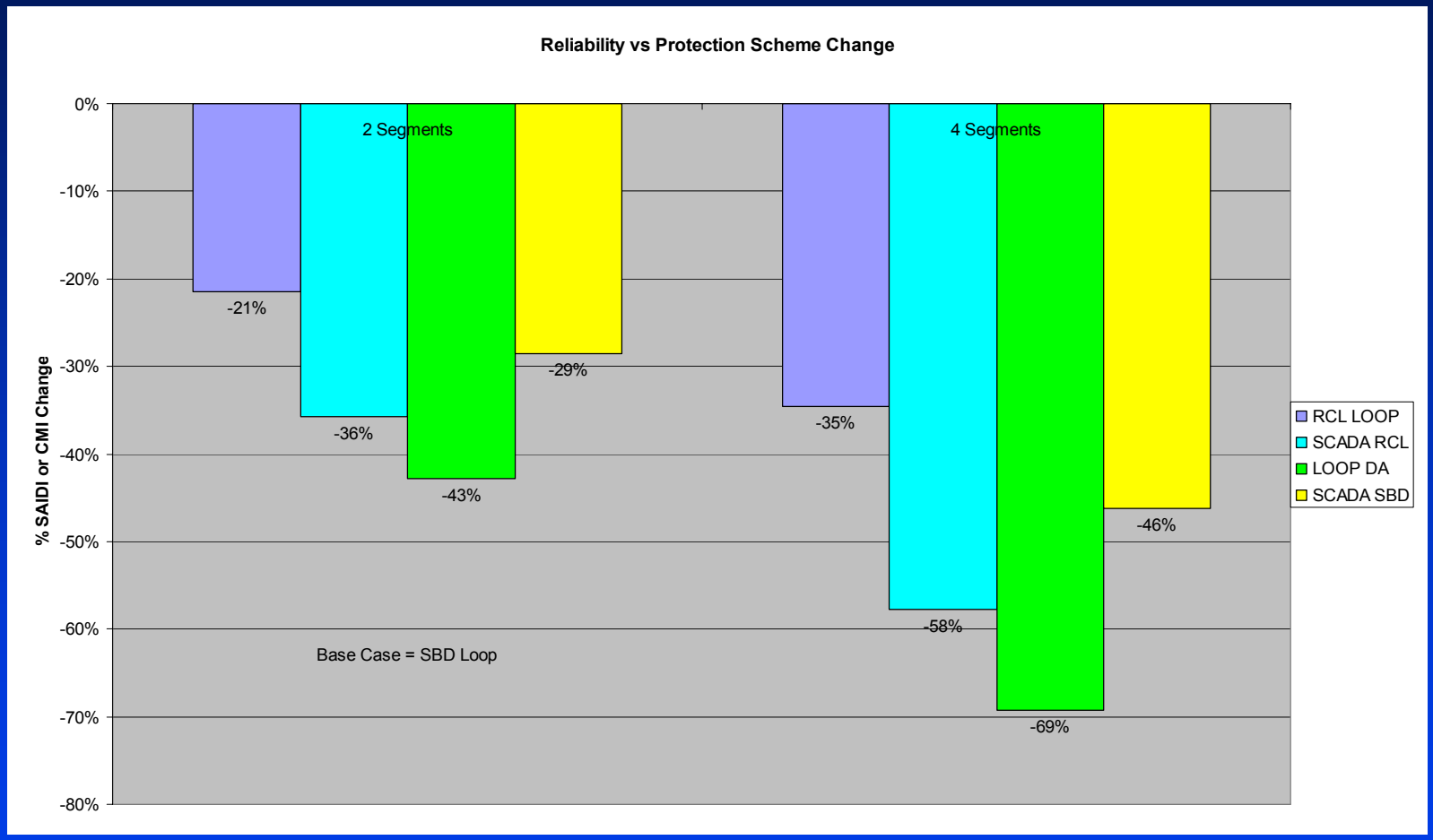
# Segments	SAIDI						
	SBD Radial	SBD Loop	RCL Radial	Loop RCL	Loop SCADA	Loop AUTO DA	SCADA SBD
1	240	240	240	240	240	240	240
2	225	210	180	165	135	120	150
3	220	200	160	140	100	80	120
4	218	195	150	128	83	60	105
5	216	192	144	120	72	48	96
6	215	190	140	115	65	40	90
7	214	189	137	111	60	34	86
8	214	188	135	109	56	30	83

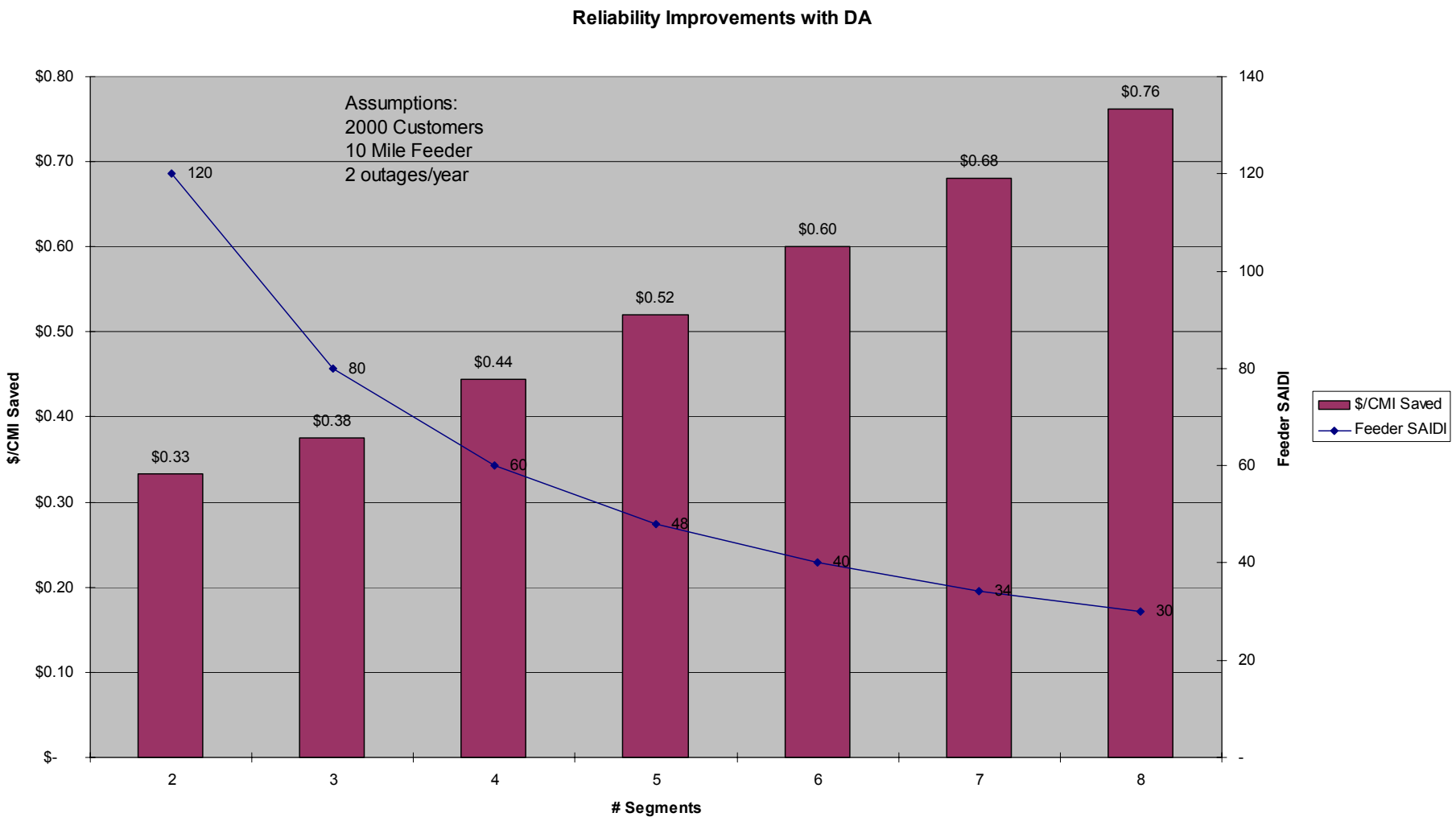
Reliability Improvement Issues

- Regulatory Requirements or Penalties
- Budget Constraints or Limitations
- Customer Service requirements
- Others

System % CMI Comparisons

2 segment vs. 4 segment




Reliability Improvements with DA
Assumptions:
2000 Customers
10 Mile Feeder
2 outages/year
$/CMI Saved
Feeder SAIDI
Segments
$0.80
$0.70
$0.60
$0.50
$0.40
$0.30
$0.20
$0.10
$-
140
120
100
80
60
40
20
-
2
3
4
5
6
7
8
$0.33
$0.38
$0.44
$0.52
$0.60
$0.68
$0.76
120
80
60
48
40
34
30
$/CMI Saved
Feeder SAIDI

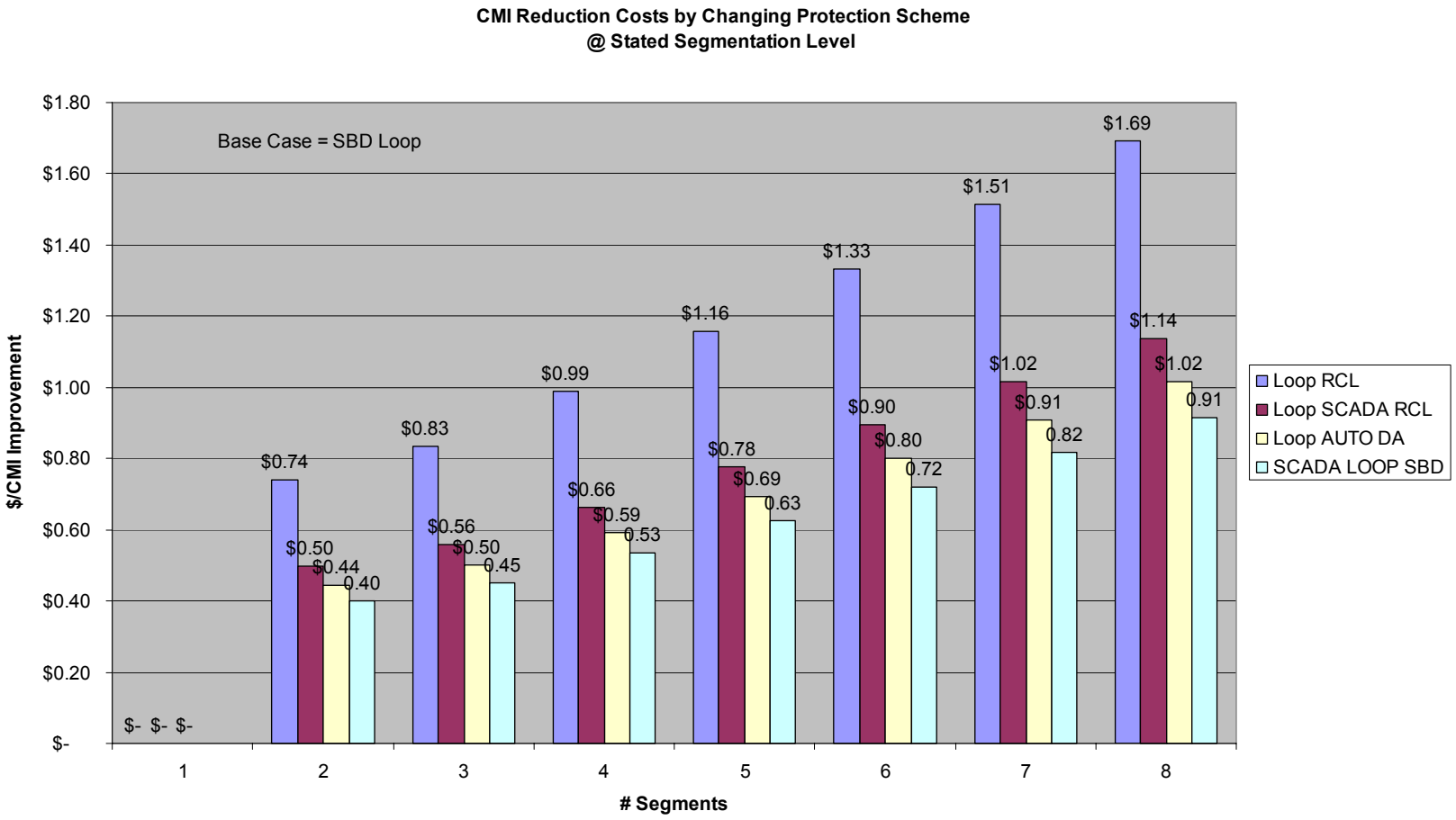
Reliability Improvement Costs & Benefits

What are your Drivers?

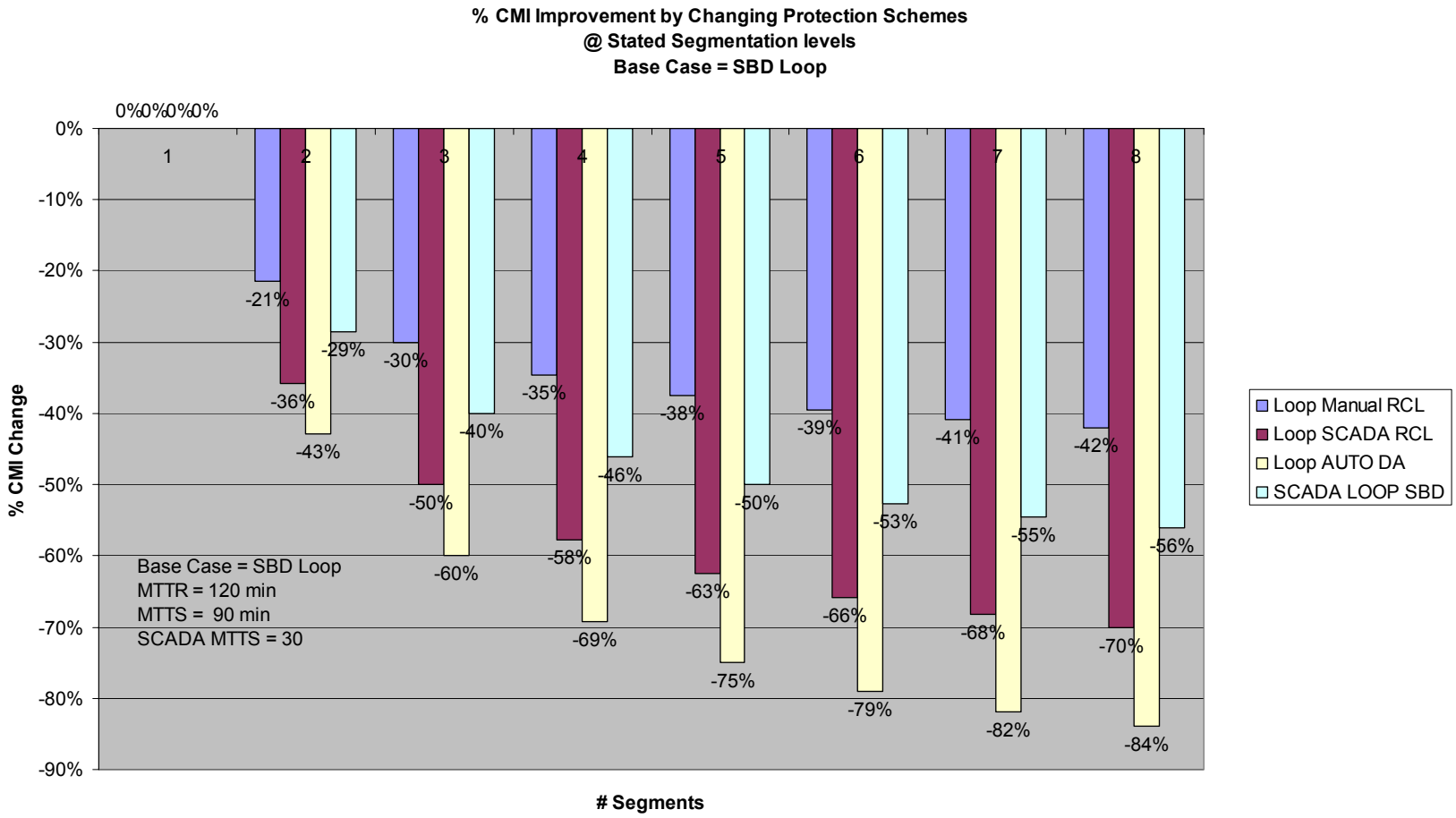
Base Case = SBD Loop with existing segmentation = # Segments

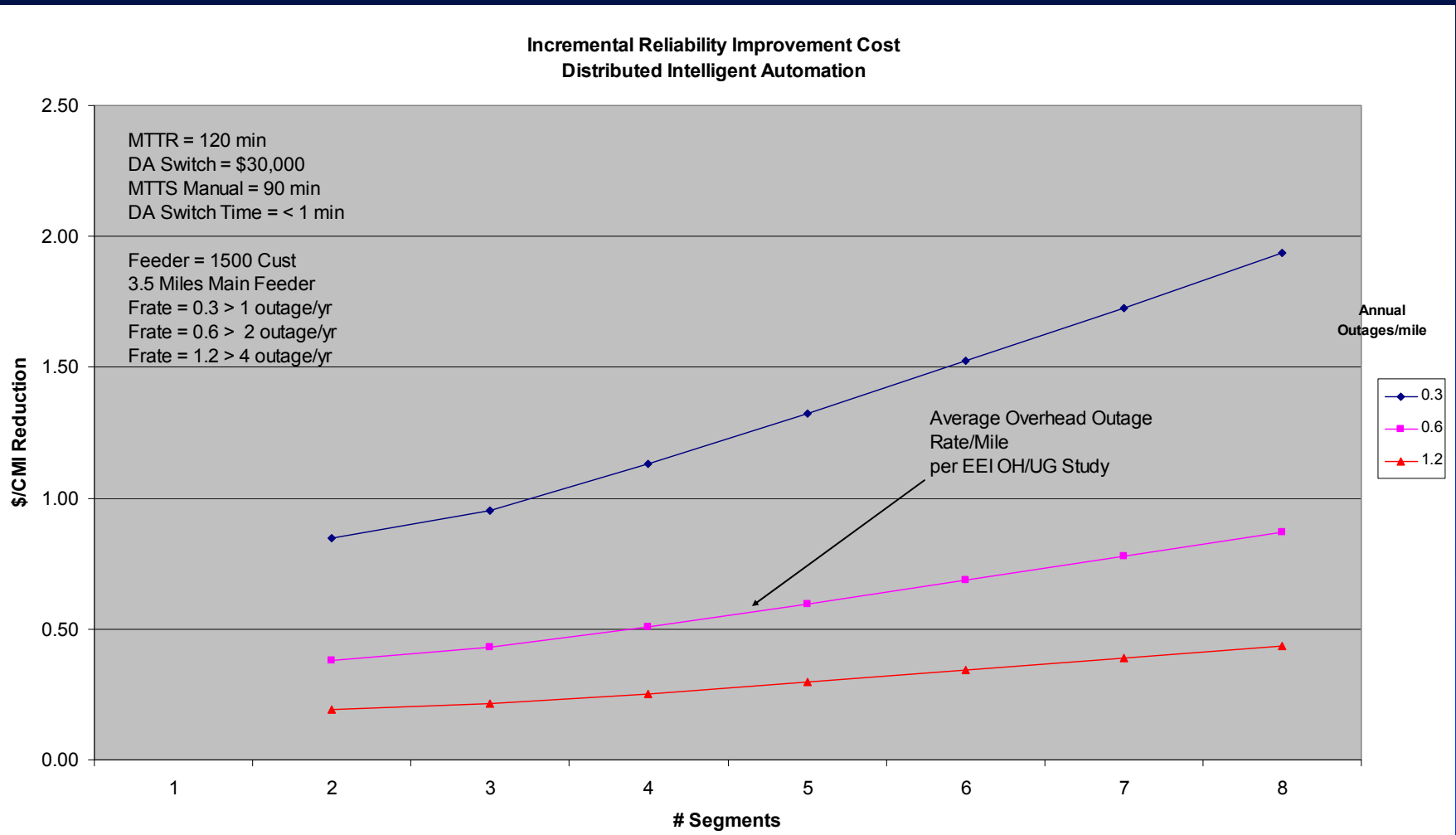
# Segments	% CMI Reduction	DA Economics CMI Changes	DA Switch Cost	$/CMI	FDR SAIDI	Avg Cust Miles for Segmentation
2	-20%	(120,000)	$ 50,000	$ 0.42	240	10,000
3	-33%	(160,000)	$ 75,000	$ 0.47	160	6,667
4	-43%	(180,000)	$ 100,000	$ 0.56	120	5,000
5	-50%	(192,000)	$ 125,000	$ 0.65	96	4,000
6	-56%	(200,000)	$ 150,000	$ 0.75	80	3,333
7	-60%	(205,714)	$ 175,000	$ 0.85	69	2,857
8	-64%	(210,000)	$ 200,000	$ 0.95	60	2,500

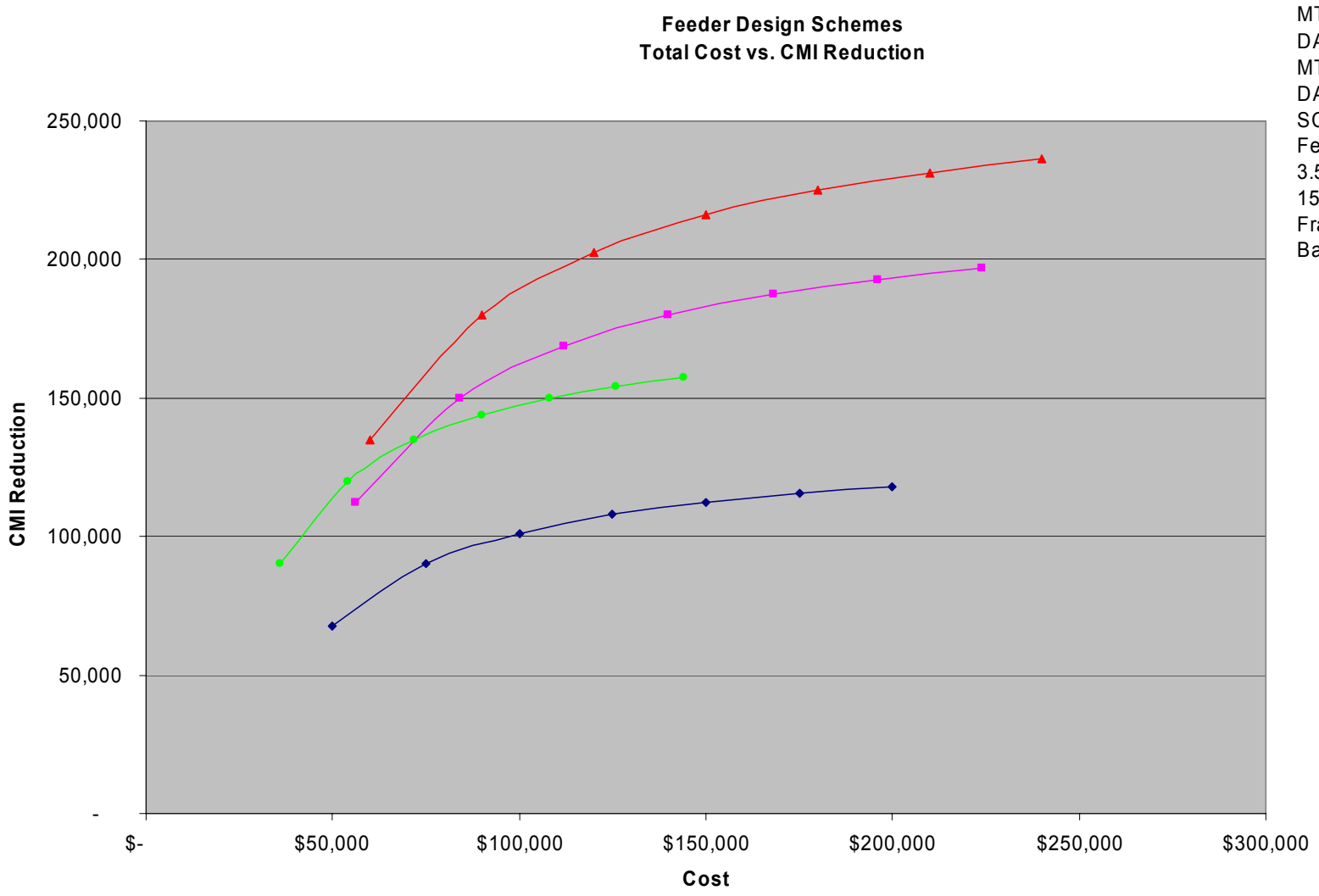
Economics of Reliability



CMI Impact of Different Protection Schemes




Incremental Reliability Improvement Cost
Distributed Intelligent Automation
MTTR = 120 min
DA Switch = $30,000
MTTS Manual = 90 min
DA Switch Time = < 1 min
Feeder = 1500 Cust
3.5 Miles Main Feeder
Frate = 0.3 > 1 outage/yr
Frate = 0.6 > 2 outage/yr
Frate = 1.2 > 4 outage/yr
Average Overhead Outage Rate/Mile per EEI OH/UG Study
$/CMI Reduction
2.50
2.00
1.50
1.00
0.50
0.00
1
2
3
4
5
6
7
8
Segments
Annual Outages/mile
0.3
0.6
1.2

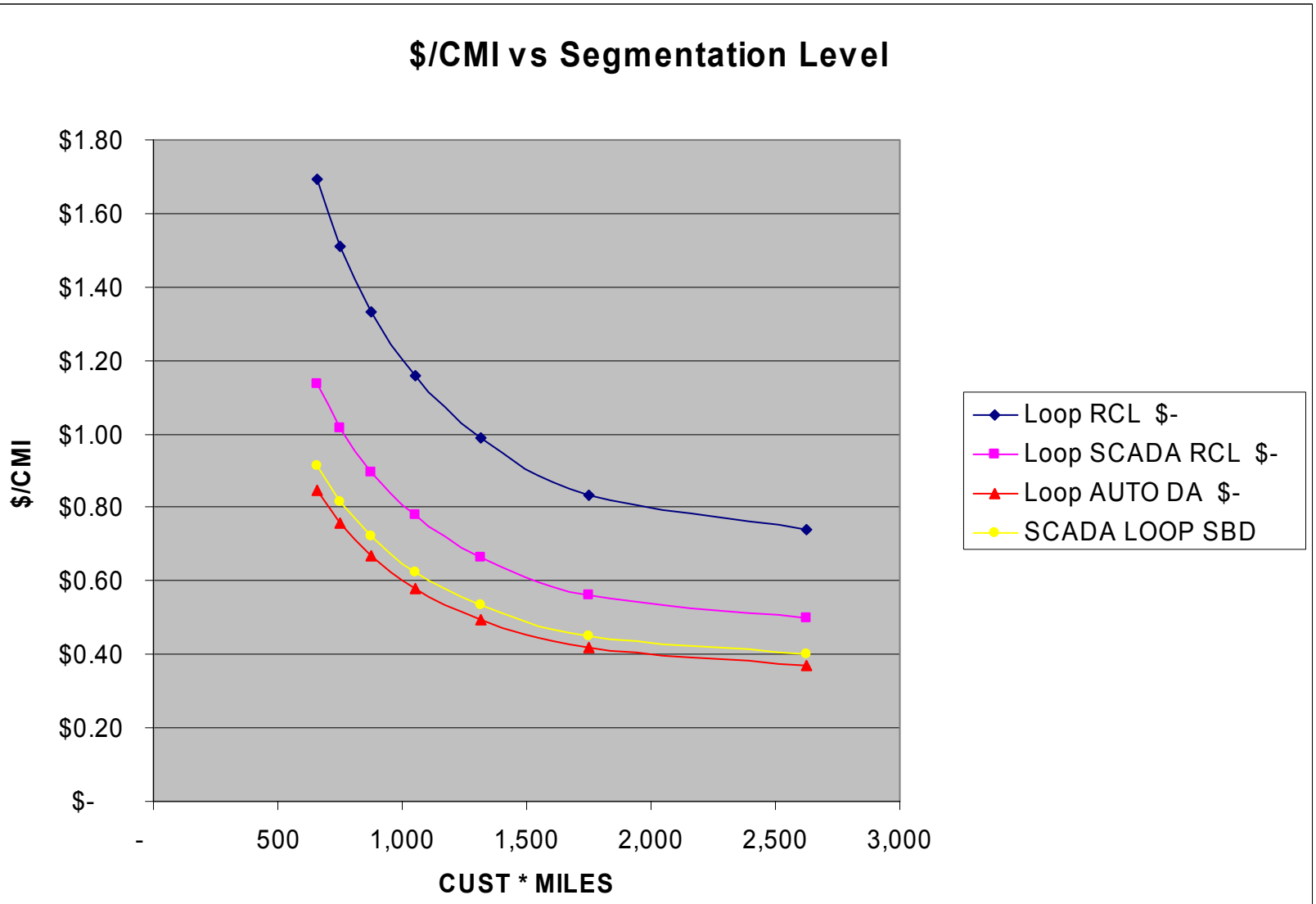


MTTR = 120 min
DA Switch = $30,000
MTTS Manual = 90 min
DA Switch Time = < 1 min
SCADA SwitchTime = 30 min
Feeder = 1500 Cust
3.5 Miles Main Feeder
1500 Customers
Frate = 0.6 faults/mile/yr
Base Case = SBD Loop

Intelligent DA Benefits

- Intelligent DA provides 2X the reliability improvement of reclosers when compared to an SBD System
- Doubling Segmentation with DA provides 50% Improvement in Reliability
- Doubling Segmentation with Reclosers provides 36% Improvement in Reliability

Segmentation level for reclosers may be limited by coordination issues


$/CMI vs Segmentation Level
$1.80
$1.60
$1.40
$1.20
$1.00
$0.80
$0.60
$0.40
$0.20
$-
$/CMI
-
500
1,000
1,500
2,000
2,500
3,000
CUST * MILES
Loop RCL $-
Loop SCADA RCL $-
Loop AUTO DA $-
SCADA LOOP SBD