SGS
Transmission Reliability Benchmarking Study

18 YEARS

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Considering the 2012 SGS Study?

- **We expect, again, to represent over 50% of the US grid, as we have every year in the past decade**
- **Commitments to participate are made in Q4-2011 and early 2012.**
- **Data is submitted in Q1-2012 (5+ years through December 31, 2011).**
- **Analysis and report production March-May, 2012**
- **Results/Participant Conference May 8-9, 2012 at Seneca-Niagara in Niagara Falls, NY.**

SGS Experience

- Statisticians, established in 1989.
- 1993, exclusive focus on T&D reliability analysis.
- 1995 began transmission reliability benchmarking.
- In 2011, SGS Transmission Reliability Benchmarking Study marked ***seventeen years*** of operation:
  - 25 participants, 50.9% of the US and 46.9% of the North American grid, based on NERC TADS mileage.
  - Represents 58% of total non-coincident total US peak MW load in 2007 (the all time US peak, EIA statistics)
  - 96% Renewal from ‘10 to ‘11

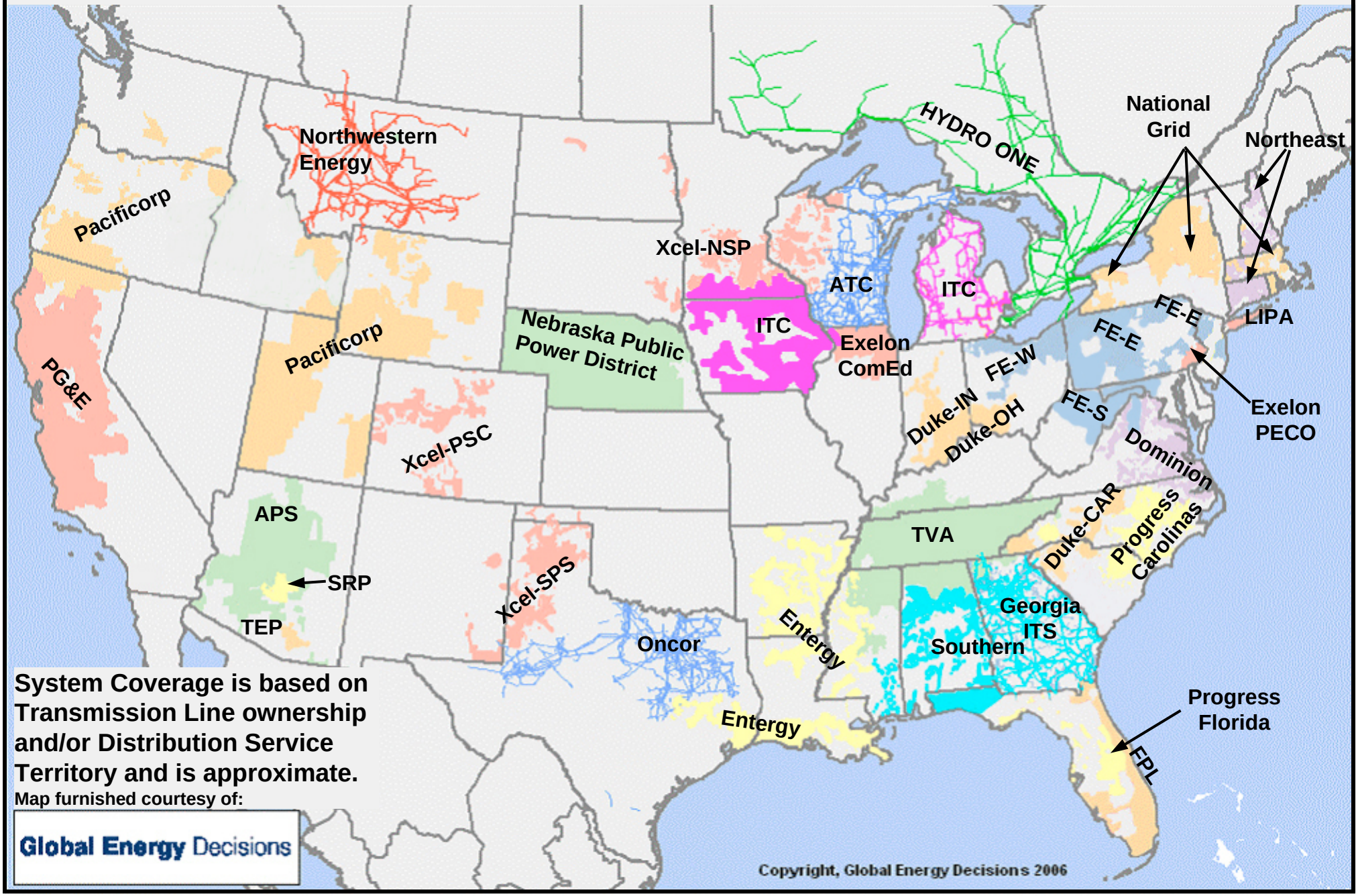
The SGS Study

- Participants pay a fee based on system size.
- Each submits 5+ years of raw outage data.
- Individual benchmarking results are reported anonymously.
- Systems may arrange for bilateral exchange of anonymous IDs.
- SGS is bound by confidentiality agreements and may not reveal any individual system results without written direction from the individual system.
- SGS may use high-level summaries for third parties and raw data for R&D activity at its discretion.

2011 SGS Study Participants

Arizona Public Service
American Transmission Co.
Dominion Virginia Power
Duke Energy
Entergy Services Inc.
Exelon Corp.
First Energy
Florida Power & Light
Georgia Transmission Corp.
Hydro One Networks
ITC Holdings Corp.
Long Island Power Authority
National Grid USA
Nebraska Public Power District
Northeast Utilities
NorthWestern Energy
Oncor Electric Delivery
PacifiCorp
Pacific Gas & Electric
Progress Energy
Southern Company
Salt River Project
Tucson Electric Power
Tennessee Valley Authority
Xcel Energy

2011 SGS Study Participant Map



2011 SGS Study Size

Voltage Class	Number Of Circuits	Percent Of Circuits	Circuit Years	Sum Length	Percent Length	Outage Sum	Percent Of Outages
Load Serving	12,757	78.38	147,505	177,522	65.20	206,414	87.39
Subtransmission	4,678	28.74	54,064	56,451	20.73	120,953	51.21
100 - 161 kV	8,079	49.64	93,441	121,071	44.47	85,461	36.18
Bulk Power	3,518	21.62	38,137	94,734	34.80	29,789	12.61
230 kV	2,418	14.86	24,671	51,857	19.05	15,311	6.48
345 - 500 kV	1,100	6.76	13,466	42,877	15.75	14,478	6.13
ALL Voltages	16,275	100.0	185,643	272,256	100.0	236,203	100.0
***Excluded Circuits**	804			10,129			

- *The 2011 Study contained 50.9% of the US grid, 46.9% of the US/Canada grid and 51.7% of all US/Canada circuits NERC TADS Inventory*
- *25 participants provide transmission service to 70 million distribution customers.*
- *Combined system peak load is approximately 472,280 MW, 58% of US Peak Load*

What is Unique About this Study?

- SGS has a unique whole-industry view of transmission data and practices based on 17 years experience running the SGS Study.
- The SGS Transmission Reliability Benchmarking Study has an *exclusive* focus on reliability. It is the largest and most complete study of transmission reliability in the world.
- SGS does not provide management or engineering consulting services. *You know your practices, costs and organization; we only measure reliability.*
- The study features the innovative *Transmission Availability Composite Score (TACS),* which SGS developed.
- The study provides solid, third party assessments of reliability and *actionable* information for maintenance, inspection and capital decision support.

The Raw Data Advantage

The SGS Study begins with raw outage data...

The benefits of using raw, circuit-level transmission outage data:

- ***Low level*** of internal resources required for participation than other benchmarking efforts.
- Assurance that all participants' data is handled in an ***identical*** manner.
- Improved consistency and validation through "data filters".
- ***Major Event Days*** identically determined using statistical screening.
- Allows between-system comparisons down to the ***individual circuit level.***

Pooling Outage Data

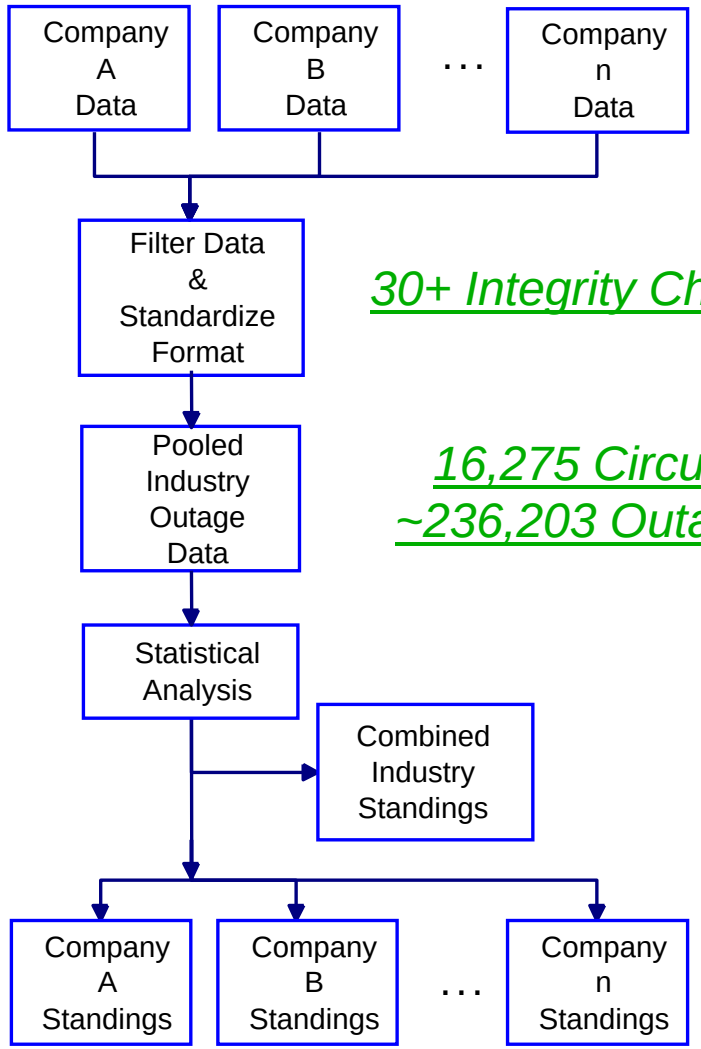
Pooling allows application of a *common* rules base to score availability.

Only through *pooling* data can you precisely determine industry standings.

Summary data is published in a common report.

Circuit-level information is provided only to the company operating the circuit.

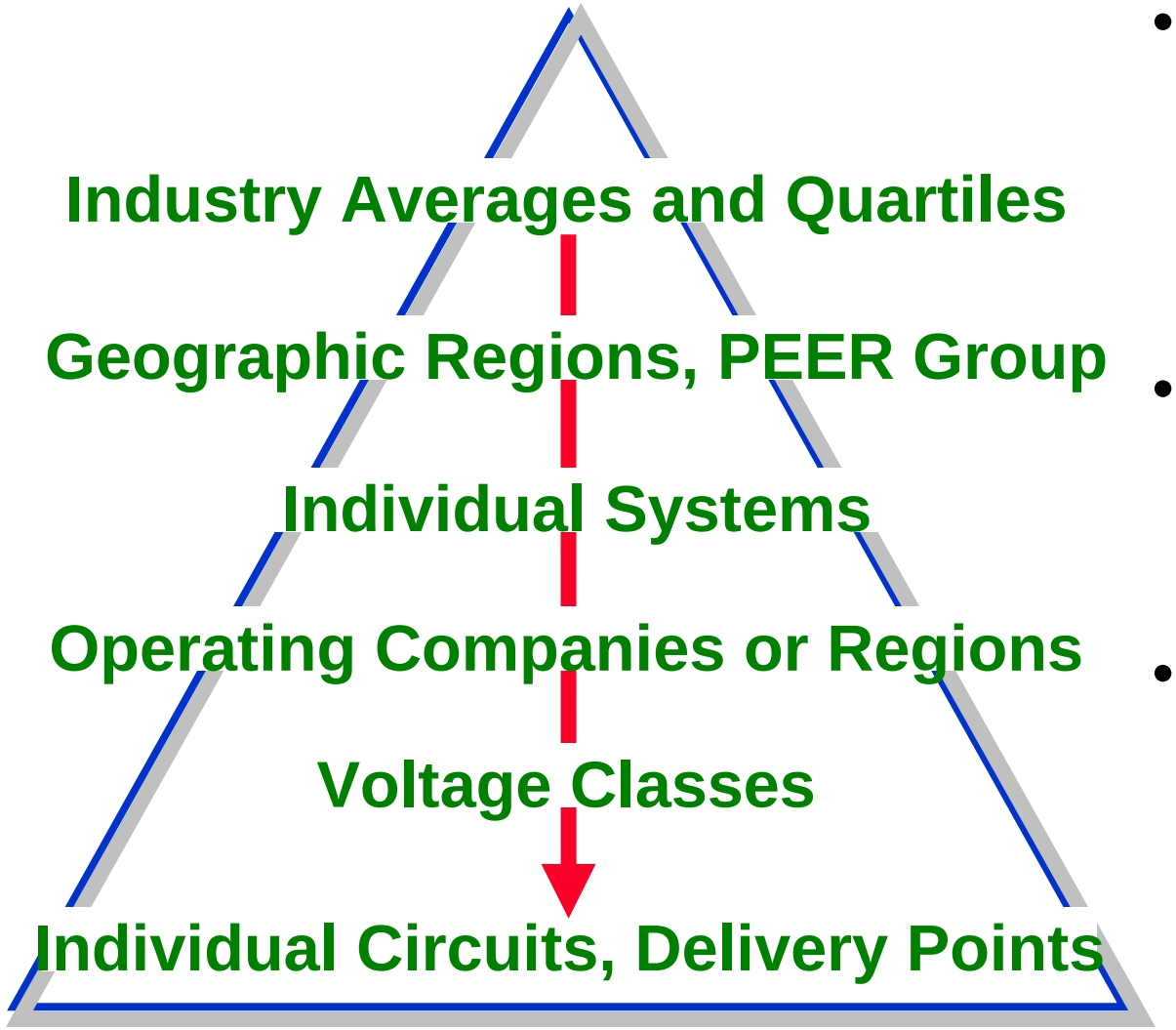
2011: 25 Systems, Different Data Formats



SGS Study Building Blocks for Reliability Improvements on Existing Transmission

Outage Data	5+ Years of raw circuit-level outage data and a circuit inventory are submitted in early Q1-2010. SGS closely works with your system to "filter" and standardize your data into a common format for all systems prior to analysis.
Circuit Importance	A *system-specific* measure of the *criticality* or *importance* for each transmission circuit is developed by your system. We encourage separate load-serving and bulk power CI metrics (quartiles, ranking or continuous values).
Performance Measures	The SGS Study produces a wide range of IEEE and Composite metrics. System and voltage class measures are used for benchmarking and trend analysis. Circuit-level metrics identify under-performing assets for reliability improvement

The Complete Reliability Picture



- The SGS Study provides a level of detail and ***granularity*** unmatched by other forums.
- Nationally-normed benchmarks down to individual circuit level.
- Other forums carry less detail and subjectivity.

How can the SGS Study be Used?

Strategic Reliability Management

- What are your long-term reliability trends? How are they measured?
- Is your relative industry position appropriate?
- Is reliability spending *proactive* or *reactive*?

Tactical Reliability Management

- What tools are used to identify underperforming assets?
- Is historical reliability consistently used in decision support?
- Is availability data complete and accurate?

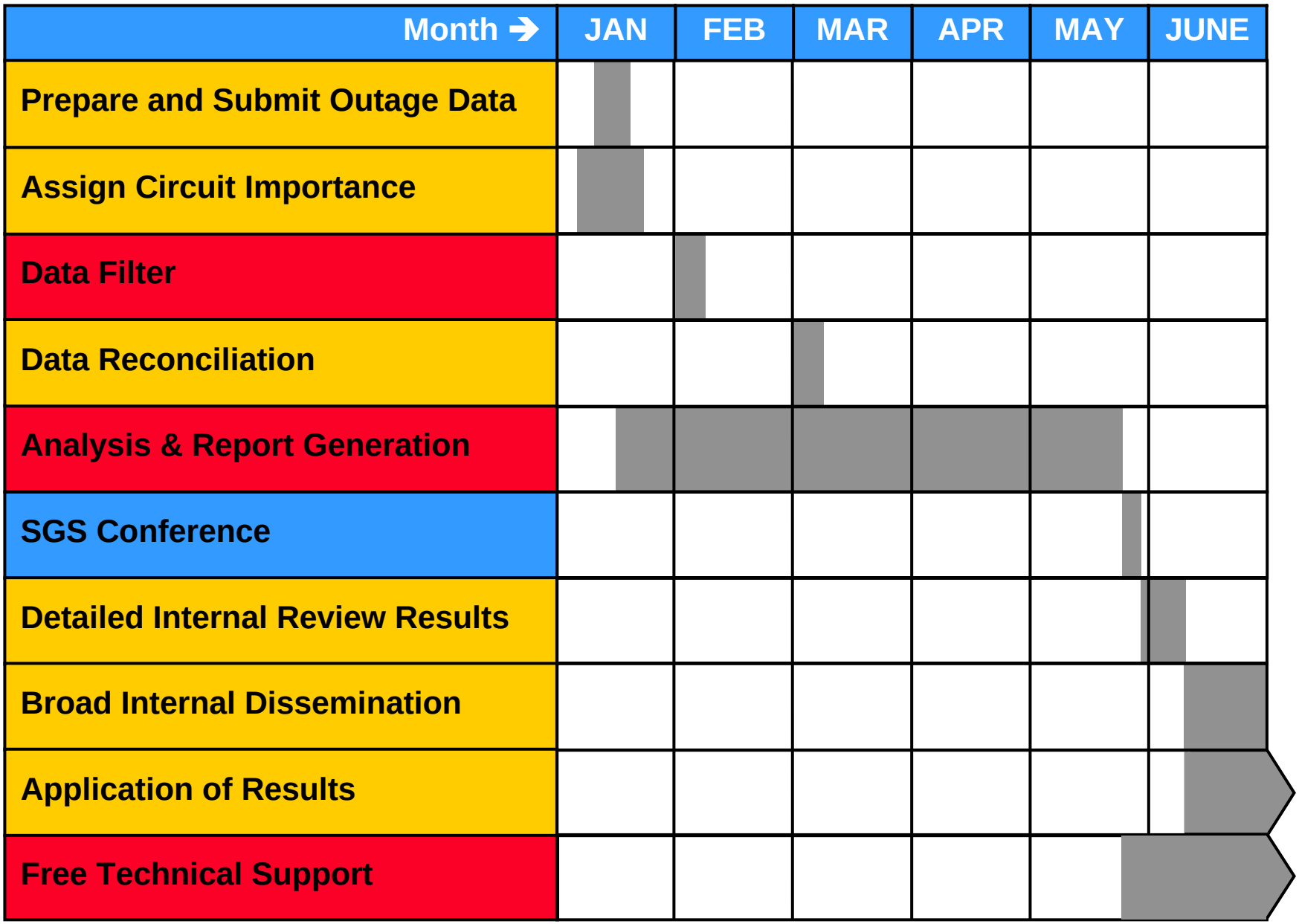
Customer Service

- Does reliability meet (or exceed) customer expectations?
- How do individual circuits serving critical customers perform versus a national sample?
- Is your TSAIFI and TSAIDI comparable to other systems?

Regulatory

- Can you demonstrate stable or improving reliability?
- How does your performance compare to your *peers* and geographic region?
- Does your transmission system have unusually large distribution impacts?

Timeline of the SGS Study



SGS Transmission Study Deliverables

Annual Conference: Results are presented in May 8-9, 2012 and includes participant presentations on internal reliability practices and management.

Report, ***Summary, Extended Summary, NERC TADS Supplement*** Technical discussion, graphical and tabular performance summaries using anonymous voltage class IDs and proprietary sections.

Transmission Availability Composite Score (TACS): Composite Scores, MTBF, outage frequency and duration, momentary and sustained outages.

NERC, IEEE & CIGRE Metrics: based on averages.

Delivery Point, Customer & Load Loss Reliability: IEEE 1366 measures.

Trend Analysis: Time-series trend charts, by voltage class, of key reliability measures and 9 outage cause categories.

Circuit-Level Measures: TACS, IEEE metrics and causes in hard copy and electronic format (proprietary).

Circuit-Level Performance GAPs: Measures to identify circuits offering the greatest improvement opportunities.

Outage Cause: Detailed circuit, voltage class and system comparisons.

Reliability Performance Normalized for Circuit Length

SGS Study Measures

SGS Transmission Lines (Auto+EFO & Auto-Only)

Transmission Availability Composite Score (TACS)
Sustained TACS
Average Circuit Outages
Average Circuit Outages MOMENTARY
Average Circuit Outages SUSTAINED
Average Circuit Outage Duration
Average Duration of an Outage (SARI)
Average Service Availability Index (% ASAI)
Forced Outage Rate per 100 Miles per Year (FOHMY)
SUSTAINED Outage Rate per 100 Miles Year (FOHMY-S)
MOMENTARY Outage Rate per 100 Miles Year (FOHMY-M)
LINES Forced Outage Rate per 100 Miles Year (FOHMY-L)
Average Circuit Outages (LINE OUTAGES ONLY)
Average Circuit Outages (Excl EXTERNAL Causes)
Average Circuit Outage Duration (Excl EXTERNAL Causes)

9 SGS Study Outage Cause Categories (Auto+EFO)
12 of 16 NERC TADS Line Metrics (Auto-Only)

Customer Metrics

Composite Score (Customer & DP)
SAIFI (Customer)
MAIFI (Customer)
SAIFI-S (Customer)
SAIDI (Customer)
CAIDI (Customer)
Customer Outages per 100 Miles
Sustained Customer Outages per 100 Miles
Customer Hours per 100 Miles

Delivery Point Metrics

SAIFI (DP)
MAIFI (DP)
SAIFI-S (DP)
SAIDI (DP)
CAIDI (DP)
DP Outages per 100 Miles
Sustained DP Outages per 100 Miles
DP Minutes per 100 Miles

NERC-SGS Study Cross Reference

12 of the 16 NERC Lines Metrics are Included in the SGS Study

Description	NERC LINES	Included SGS Study
Element Total Automatic Outage Frequency	TOF	✓
Element Sustained Outage Frequency	SOF	✓
Element Momentary Outage Frequency	MOF	✓
Element Sustained Outage Duration Time	SODT	✓
Element Sustained Outage Mean Time to Repair	MTTR	✓
Mean Time Between Sustained Element Outages (Mean "Up Time")	MTBF	✓
Median Time to Repair Sustained Element Outage Failures	MdTTR	✓
Element Availability Percentage	APC	✓
Percentage of Elements with Zero Automatic Outages	PCZO	✓
Percent of Element Automatic Outages associated with Disturbance Report (either OE-417 or EOP-004)	PCDR	n/a
Circuit Total Outage Frequency, Mileage Adjusted	$TCOF_{100CTmi}$	✓
Circuit Sustained Outage Frequency, Mileage Adjusted	$SCOF_{100CTmi}$	✓
Circuit Momentary Outage Frequency, Mileage Adjusted	$MCOF_{100CTmi}$	✓
Multi Circuit Total Outage Frequency, Mileage Adjusted	$TMCOF_{100STmi}$	n/a
Multi-Circuit Sustained Outage Frequency, Mileage Adjusted	$SMCOF_{100STmi}$	n/a
Multi-Circuit Momentary Outage Frequency, Mileage Adjusted	$MMCOF_{100STmi}$	n/a

Transformer, Multi-Circuit and Disturbance Report data are not submitted to SGS and these Metrics are not included in the SGS Study

Differences Between SGS & TADS

SGS Study	NERC TADS
•Subtransmission through EHV	•Bulk Power only, 100 kV is coming
•Statistics for Customer, DPs, Load Loss	•No customer, delivery point or load loss
•Statistical screening of “Major Event Days”	•No provision for screening any events
•No multi-circuit structure analysis	•Includes multi-circuit structure benchmarks
•Momentary <= 60 seconds	•Momentary < 1 minute
•Sustained > 60 seconds	•Sustained >= 1 minute
•Single cause descriptor	•Two-tiered cause description
•10 cause codes	•17 cause codes
•Includes Automatic-only and Automatic + Emergency Forced Manual outages (EFO)	•Automatic-only outages in Phase 1, Emergency Manual & Scheduled in Phase 2 (in 2010)
•Transmission Lines Only	•Transmission Lines & EHV Transformers
•Flexible data submission model	•Rigid data model, 12 Excel spreadsheets
•“Reasonably” consistent data	•Mandatory data consistency
•5+ years of data, all good data from 1990 forward may be used	•Annual data from 2008 and beyond only; no retrospective data submission
•Long term trend charting	•Trend charting is many years off
•Wide array of benchmarks for all TOs, regions, quartiles, top decile, industry	•Highly restrictive; benchmarks for TO, region and industry only
•16th Annual Report in May 2011	•Third Annual report Q3-2011
•Thoroughly tested and scrutinized by user community	•2010 report due in Q3-2011, changes expected with Scheduled and EFOdata
•Fee based participation	•It is **Free**, included in NERC dues
•Statisticians, small business	•Engineers, quasi-governmental bureaucracy

SGS Transmission Study Report

The **Report** is delivered in PDF format. Contains discussion, interpretation, commentary and statistical details. Report Contents:

- **Tab 1: Study Information**
- **Tab 2: Discussion**
- **Tab 3: Application Guide**
- **Tab 4: Statistical Appendix**
- **Tab 5: TACS and IEEE Metrics (All Reported Outages)**
- **Tab 6: TACS and IEEE Metrics (Automatic Outages Only)**
- **Tab 7: Outage Cause Charts**
- **Tab 8: Circuit Listings and Proprietary Output**
- **Tab 9: Statistical Comparisons**
- **Tab 10: Trend Charts and Regression (Proprietary)**
- **Tab 11-12: Delivery Point and Customer (Limited Distribution)**
- **Tab 13: Load Loss Pilot Study (Limited Distribution)**
- **Tab 14: Cable Analysis (Limited Distribution)**

Key Deliverable Examples

Bar Charts

Trend Charts

Summary Position Charts

Outage Cause Charts

Outage Cause Trend Charts

Customers & Delivery Points

Circuit-Level Output

Bar Charts - Example

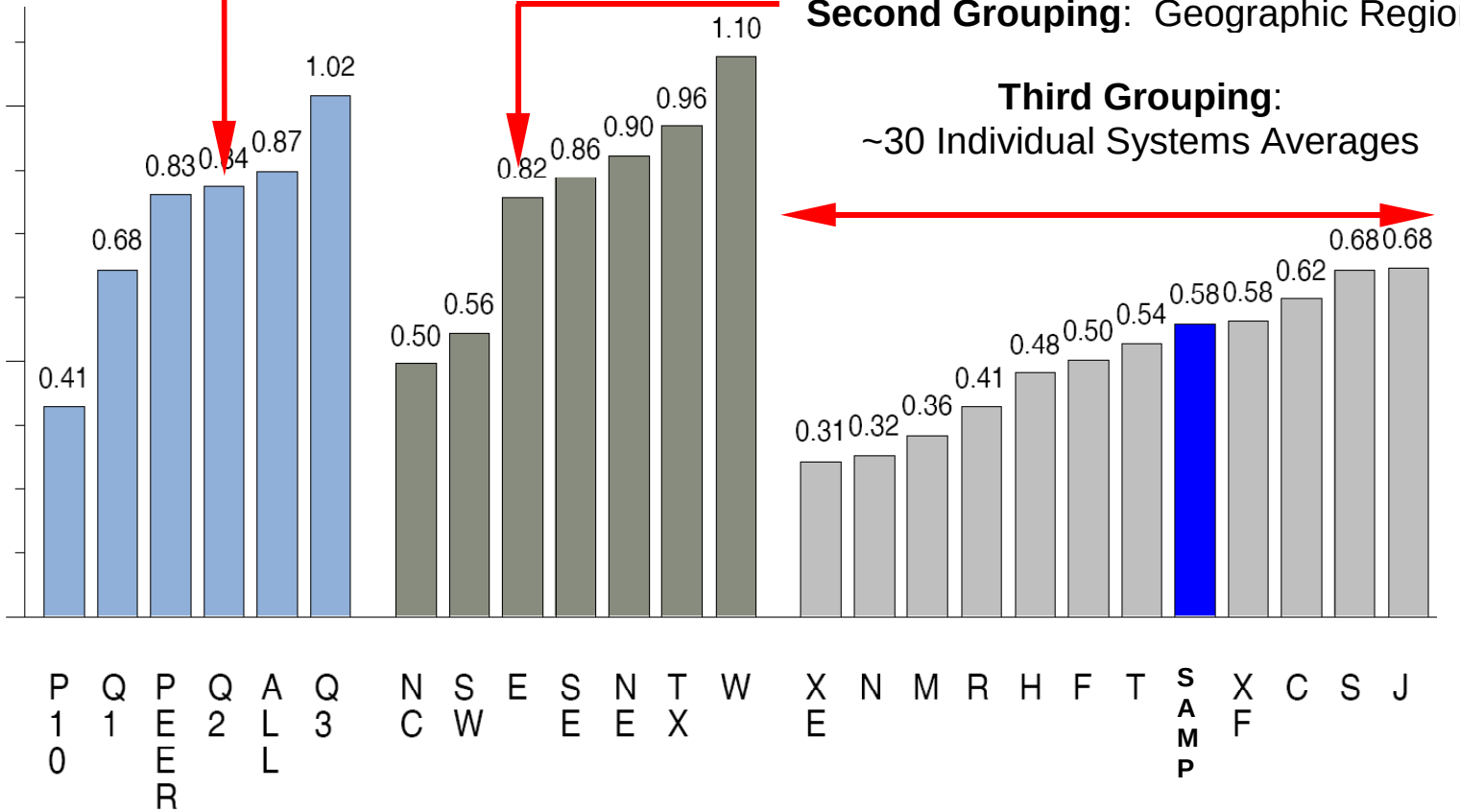
Summary Bar Charts

First Grouping

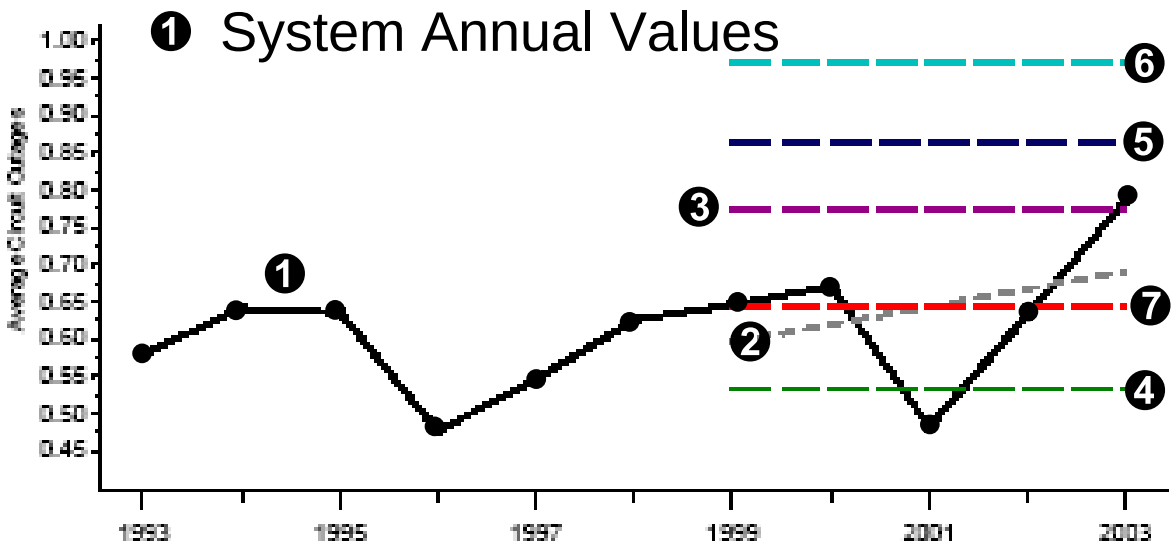
P10: Top Decile (Best 10%)
Q1: Top Quartile (25% above, 75% below)
Q2: Median (50% above, 50% below)
ALL: Mean (Average) of ALL Systems
Q3: 3rd Quartile (75% are better)
PEER: Self-selected Peer Group

Second Grouping: Geographic Regions

Third Grouping:
~30 Individual Systems Averages



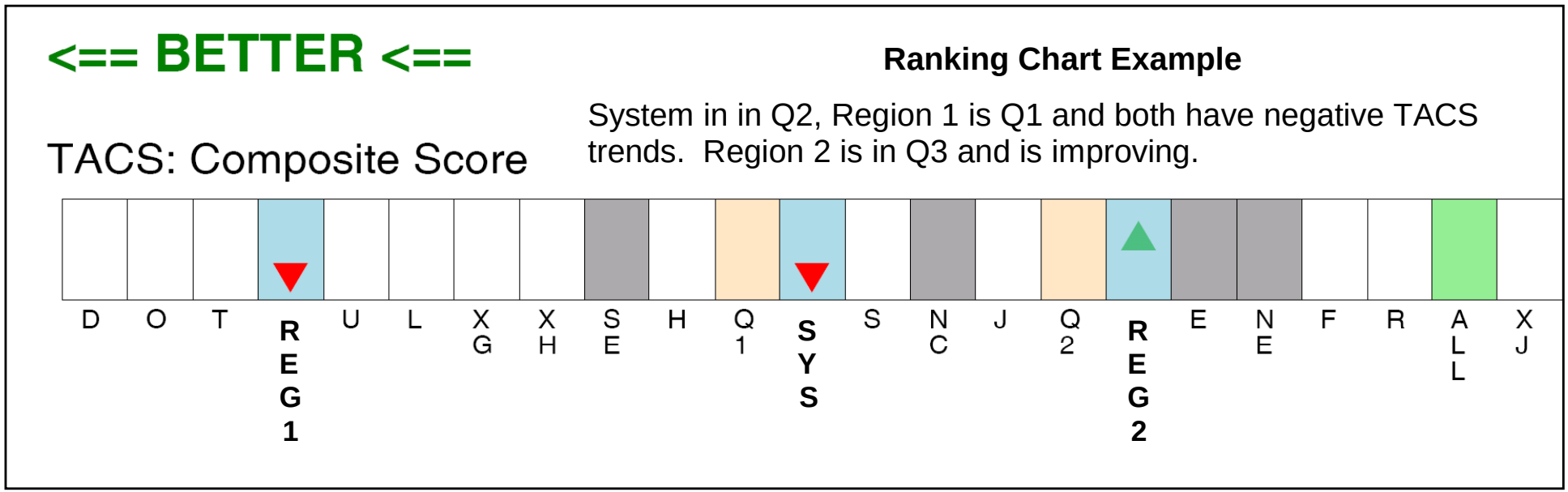
Trend Charts - Example



5 Year Average References

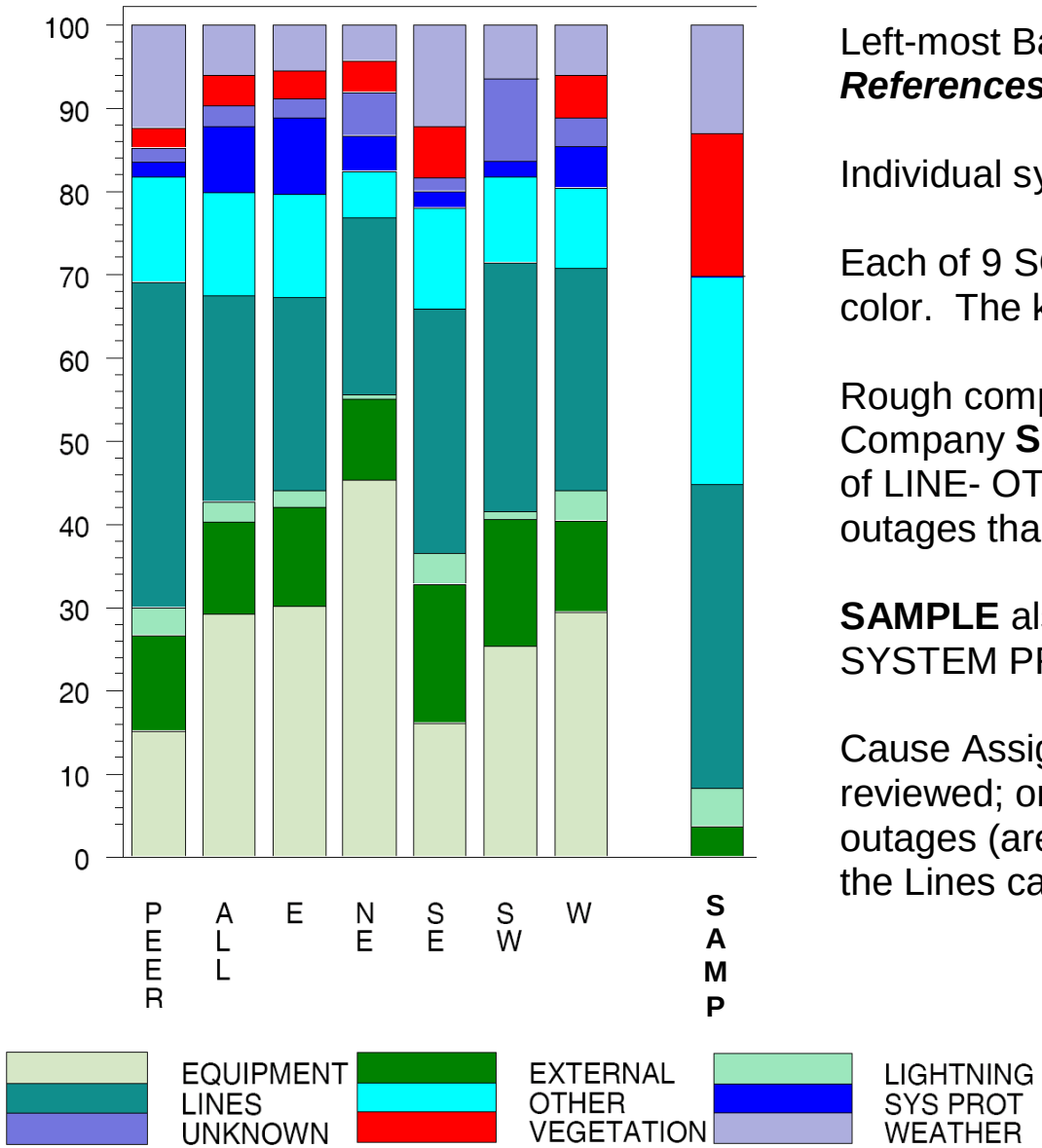
❸ ALL System Average
❹ Q1 First Quartile
❺ PEER Group
❻ Geographic REGION
❼ SYSTEM (5 Year Average)
❷ System 5 YR Trend Line

Summary Position Charts - Example



- The Ranking Charts provide at-a-glance summary of position and trend. External references are color-coded.
- Values are *point estimates* and should be taken in context with other information.

Outage Cause Charts - Example



Left-most Bars are provided for the ***External References***

Individual systems are in the seond group.

Each of 9 SGS Categories are keyed to a different color. The key is at the bottom of the Bar Charts.

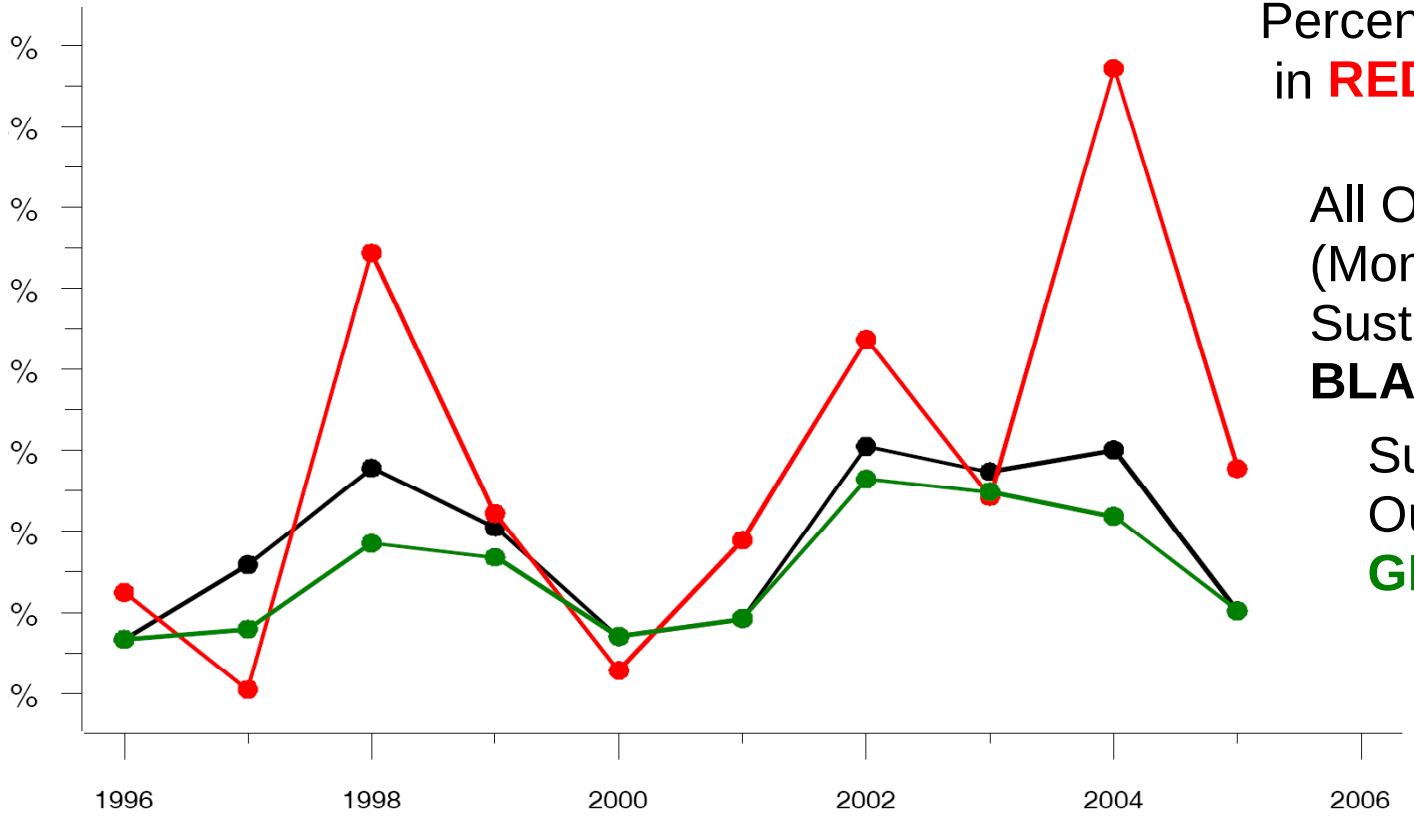
Rough comparisons can be made… For instance, Company **SAMPLE** has much higher proportions of LINE- OTHER- and VEGETATION-related outages than its peer group.

SAMPLE also has a negligible proportion of SYSTEM PROTECTION outages.

Cause Assignment at **SAMPLE** should probably be reviewed; one would expect *some* Equipment outages (are some being erroneously assigned into the Lines category?)

Outage Cause Trend Charts

EQUIPMENT Outage Cause Trend

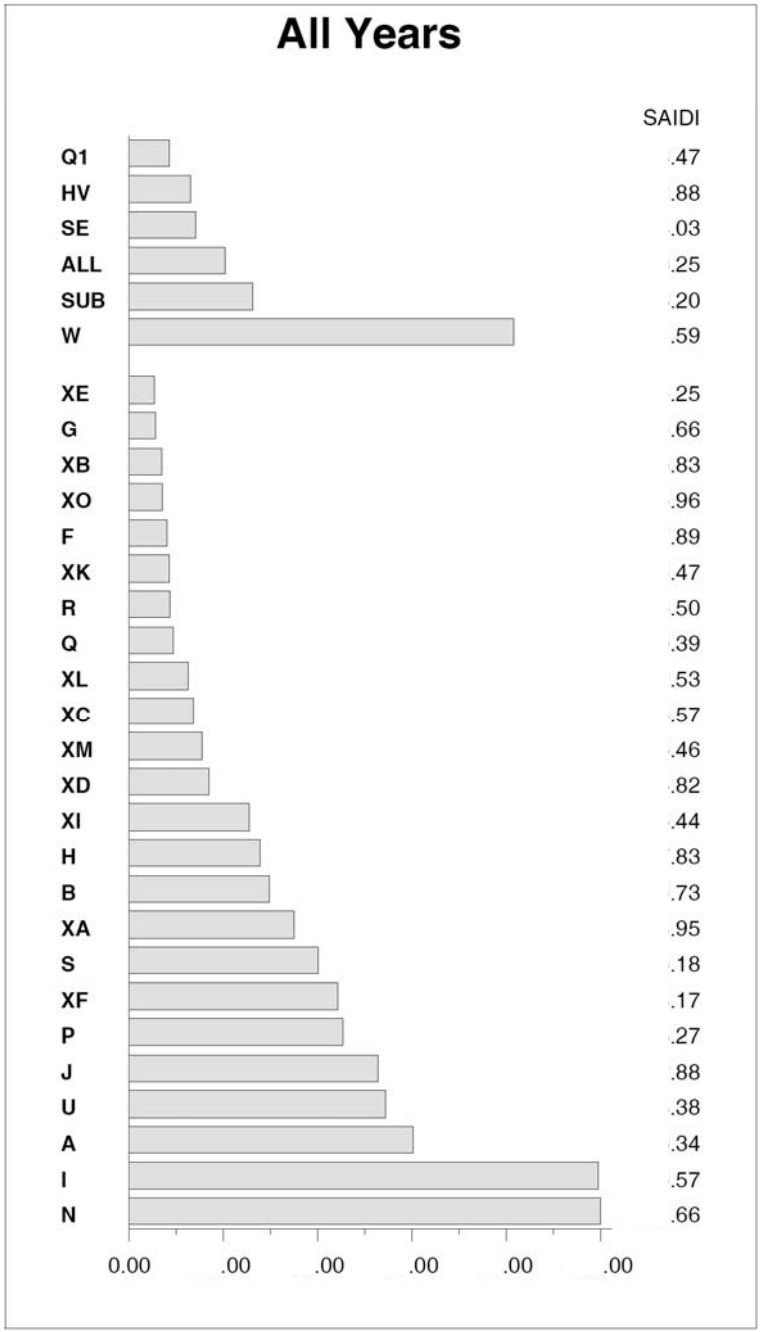


Duration Percentage in **RED**

All Outages (Momentary and Sustained) in **BLACK**

Sustained-Only Outages in **GREEN**

Customers & Delivery Points



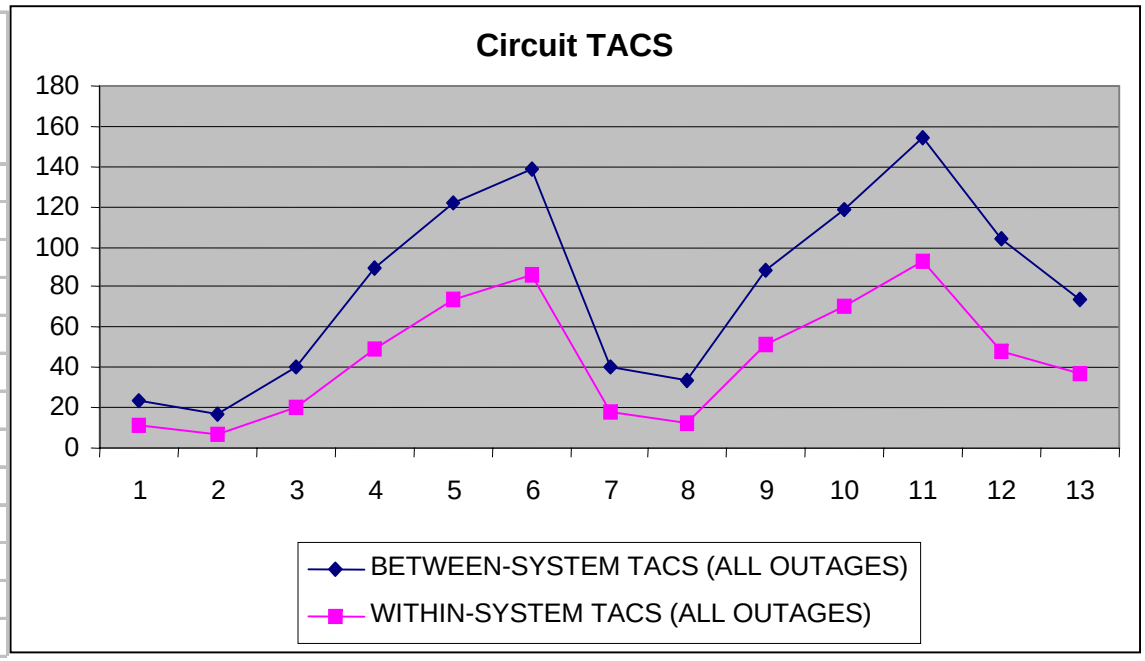
- IEEE Std 1366 Standard Measures are provided for both customer and/or delivery point impacts from transmission line outages.
- Up to 5 years of data is used.
- Circuit-level measures are also provided.
- 19 of 25 member systems provided Customer and/or DP data in 2011.
- Analysis based on transmission circuit outages affecting Customers or Delivery Points.

Circuit-Level Analysis: Detailed Tabular and Electronic Output

Circuit ID			All Outages TACS									Sustained TACS		
CIRC ID	kV	Last Outage	BETW SYS TACS	WITHIN SYS TACS	PCT	IMP	GAP	BULK	GAP (B)	LOAD	GAP (L)	WITHIN SYS SUST TACS	GAP (SB)	GAP (SL)
0328	500	14JUN05	194	239	24	97	**-73**	87	**-63**	.	**.**	184	**-69**	**.**
0333	500	30JUL05	186	227	23	95	**-72**	79	**-56**	.	**.**	177	**-61**	**.**
0329	500	26MAR05	255	284	28	98	**-70**	94	**-66**	.	**.**	239	**-70**	**.**
0330	500	06JUN05	293	317	32	99	**-67**	96	**-64**	.	**.**	277	**-68**	**.**
0288	230	17JUL05	295	316	32	96	**-64**	83	**-51**	.	**.**	272	**-56**	**.**
0300	230	26JUL05	299	325	32	95	**-63**	77	**-45**	.	**.**	274	**-50**	**.**
0324	345	04SEP05	290	296	30	92	**-62**	60	**-30**	.	**.**	266	**-33**	**.**
0319	230	25DEC05	162	189	19	80	**-61**	25	**-6**	.	**.**	147	**-10**	**.**
0323	345	06DEC05	285	319	32	92	**-60**	60	**-28**	.	**.**	280	**-32**	**.**
0065	69	04DEC05	79	108	11	69	**-58**	.	**.**	82	**-71**	200	**.**	**-62**

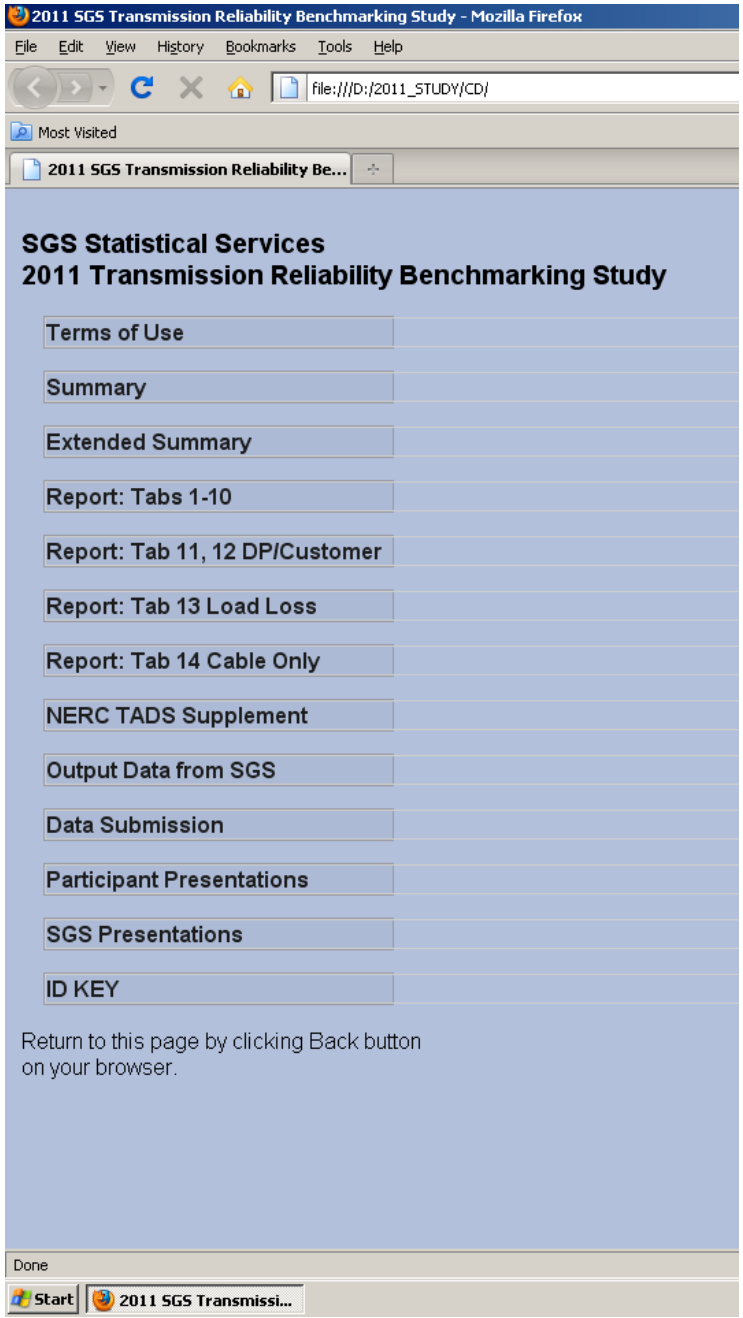
Electronic Output Example

CIRCUIT ID	END OF REPORTING DATE	LAST RECORDED OUTAGE DATE	BETWEEN-SYSTEM TACS (ALL OUTAGES)	WITHIN-SYSTEM TACS (ALL OUTAGES)
502	31-Dec-02	23-Dec-02	23	11
502	31-Mar-03	27-Mar-03	17	7
502	30-Jun-03	17-May-03	40	20
502	30-Sep-03	17-May-03	89	49
502	31-Dec-03	17-May-03	122	74
502	31-Mar-04	17-May-03	139	86
502	30-Jun-04	17-May-04	40	18
502	30-Sep-04	31-Jul-04	33	12
502	31-Dec-04	31-Jul-04	88	51
502	31-Mar-05	31-Jul-04	118	70
502	30-Jun-05	31-Jul-04	154	93
502	30-Sep-05	25-Sep-05	104	48
502	31-Dec-05	15-Nov-05	74	37



- Select individual circuits for customized trend charts
- Aggregate different circuit types (e.g., steel vs. wood structures)
- Compare relative or absolute performance at different points in time.

SGS Study CD



The SGS Study CD contains complete output:

- Summary
- Extended Summary
- Study Report Tabs
- Report Tabs 11-14 (Limited Distribution)
- NERC TADS Supplement
- Output Data Files
- Original Data Submission, Data Filters
- Participant Presentations
- SGS Resource Material

What is TACS?

Transmission **A**vailability **C**omposite **S**core: Is a one-number summary of reliability performance, using 5 years of age-weighted outage data consisting of:

Recent Time Between Failures:

Snap-shot of recent performance; time since last outage.

Mean Time Between Failures:

Long running average

Outage Duration:

Sum of restoration time

Outage Frequency:

Sum of total forced outages

TACS Characteristics

Transmission Availability Composite Score

- A one-number summary of reliability performance.
- Uses 5 years of age-weighted outage data.
- *A historical measure of risk.*
- A relative measure, based on percentiles.
- Calculated at the circuit level, rolled up to voltage class level.
- Has direct application in reliability decision support.
- Computed on a *between-system* (for benchmarking) and *within-system* (for decision support) basis.

Effective Asset Management: Matching Performance with Expectations

- **Performance:**
  - Reliability measures are the **experience** of a circuit or system.
  - Computation methods are *generic* to all systems.
- **Expectations:**
  - Not all circuits have equal importance to customers, transfer capacity or system operations.
  - It is essential to quantify the **importance** (criticality) of each transmission and distribution circuit.
  - Circuit importance is *system-specific* (based on design, redundancy and standards).
  - Circuit importance defines customer **expectations**.
- ***Compare*** **performance** (experience) with **importance** (expectations).

Circuit Importance

- System-specific definition.
- Quantifiable and objective combination of measures.
- ***Not*** a dynamic quantity that changes with each new set of operating conditions. Fairly static, adjusted annually.
- Provide the asset manager a list of reliability *expectations*
- Allows stakeholders to compare actual performance to the expectations.
- ***Two sets*** of CI measures, one for ***load-serving*** circuits and another for ***bulk power***.
- Develop with a broad cross-section of the TO and possibly stakeholders.

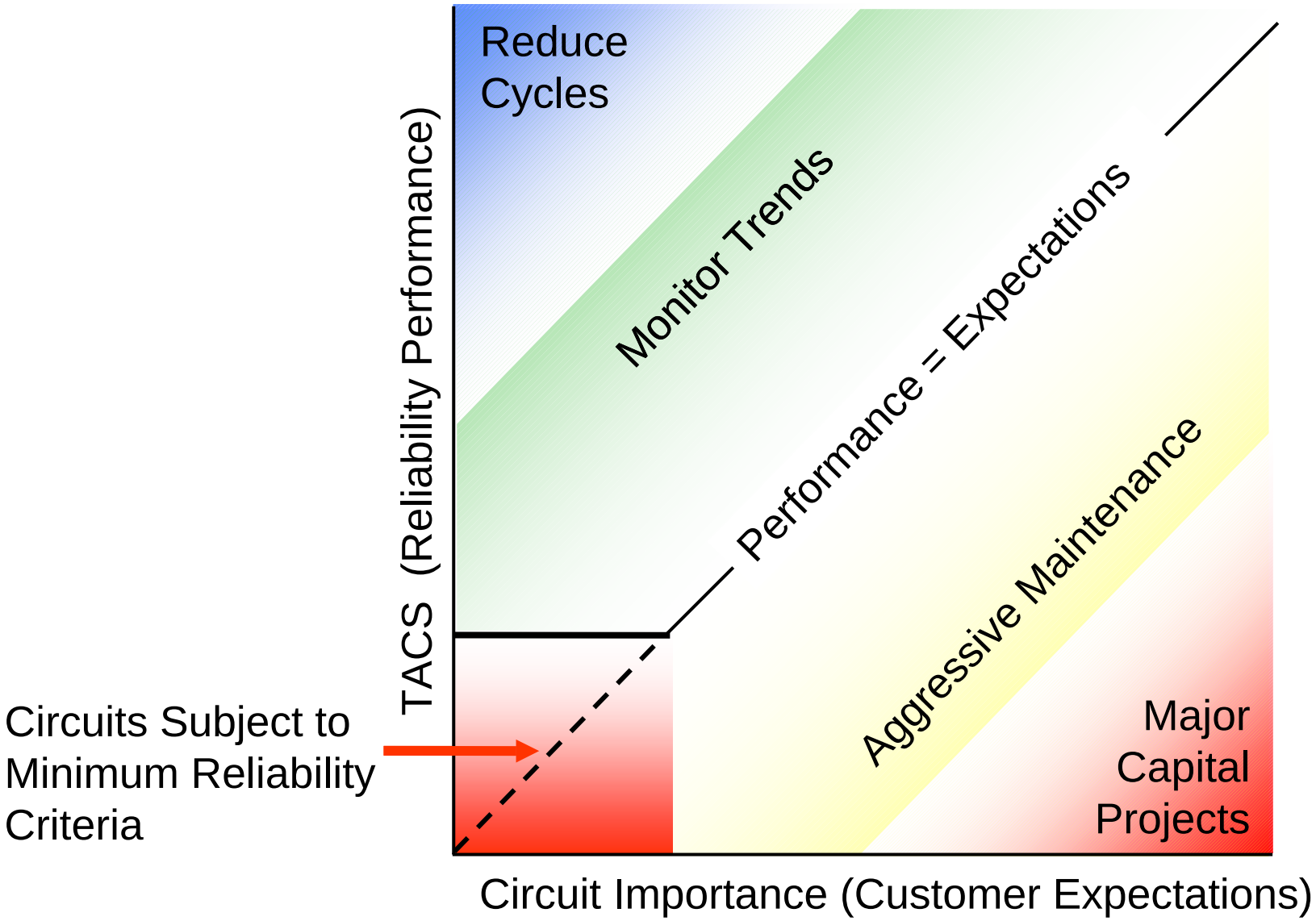
Load-Serving Circuit Importance

- *Average and/or Peak Loads:* Average or peak MW or MVA from: delivery point metering, planning studies, KVA per customer, etc. Partitioned into *dependent load* and *through flows*.
- *Customer and Delivery Point Totals:* Customer and DP count aggregated on a circuit level.
- *Customer Class:* Break-down by consumers (residential, commercial, industrial) and producers.
- *Financial Impact on Customers:* Process and high-tech customers can experience significant financial losses from outages.
- *Ease of Repairs and Access:* Circuits which present difficult repair problems (e.g., cable), located in difficult terrain or far from crew bases should be identified.
- *Inspection Results:* Deficiencies noted in inspection cycles.
- *Redundancy and Ease of Restorations through Switching*

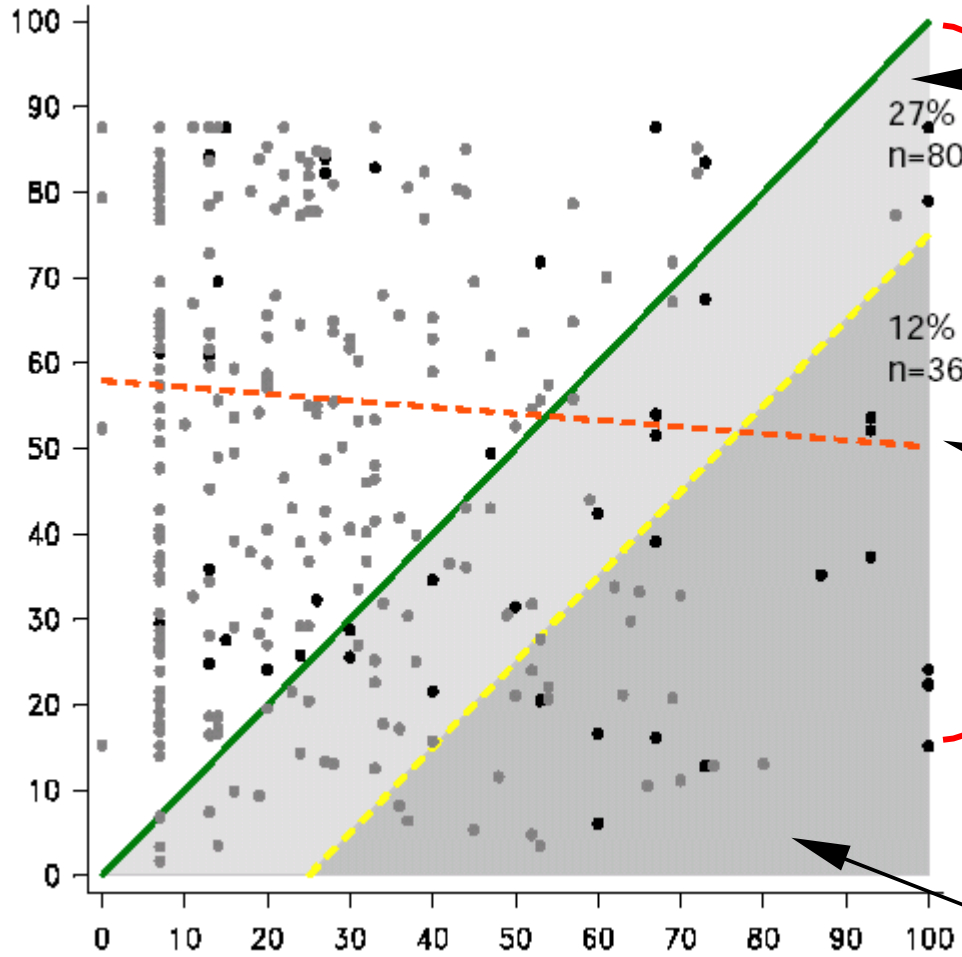
Bulk Power Circuit Importance

- *Average and/or Peak Loads and Flows:* Peak load or mean value from SCADA data or power flow study under n-0, n-1, etc.
- *Load Loss, Redispatch, Marginal Prices:* Load loss, generation redispatch, effects on Marginal Prices which would results from a line outage under n-1 contingencies.
- *Revenue Contribution:* Contribution of revenue for each line.
- *Critical Paths and Flowgates:* Lines on identified critical paths or part of “flowgates”.
- *Voltage Support:* Some lightly loaded or lower voltage lines play an important role in voltage support.
- *Power Quality:* Fault current simulations estimate voltage dips on delivery busses from specific circuit outages.
- *Inspection Results:* Deficiencies noted in inspection cycles.
- *Ease of Repairs and Access*

Actionable Reliability Information



GAPS: TACS vs. CI Percentiles



TACS Percentile

Performance = Expectations *(Ideal Relationship)*

Actual Relationship

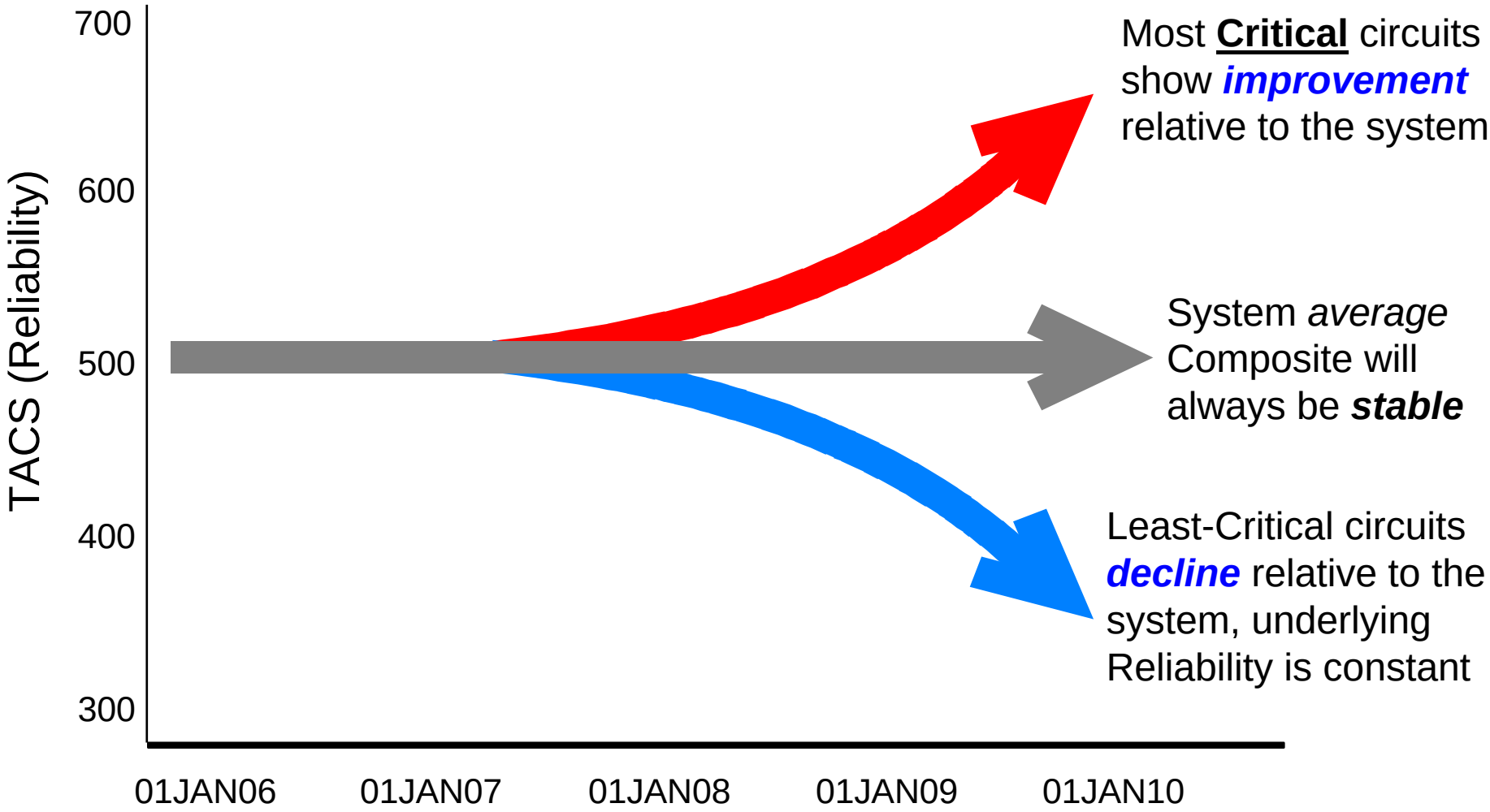
Circuits in **gray** region have *Performance **below** Expectations*

Circuit Importance
(lowest ➔ highest)

GAPs: Circuit-Level Output

Circuit ID			All Outages TACS									Sustained TACS		
CIRC ID	kV	Last Outage	BETW SYS TACS	WITHIN SYS TACS	PCT	IMP	GAP	BULK	GAP (B)	LOAD	GAP (L)	WITHIN SYS SUST TACS	GAP (SB)	GAP (SL)
0328	500	14JUN09	194	239	24	97	-73	87	-63	.	.	184	-69	.
0333	500	30JUL09	186	227	23	95	-72	79	-56	.	.	177	-61	.
0329	500	26MAR09	255	284	28	98	-70	94	-66	.	.	239	-70	.
0330	500	06JUN09	293	317	32	99	-67	96	-64	.	.	277	-68	.
0288	230	17JUL09	295	316	32	96	-64	83	-51	.	.	272	-56	.
0300	230	26JUL09	299	325	32	95	-63	77	-45	.	.	274	-50	.
0324	345	04SEP09	290	296	30	92	-62	60	-30	.	.	266	-33	.
0319	230	25DEC09	162	189	19	80	-61	25	-6	.	.	147	-10	.
0323	345	06DEC09	285	319	32	92	-60	60	-28	.	.	280	-32	.
0065	69	04DEC09	79	108	11	69	-58	.	.	82	-71	200	.	-62

Example of Sound Strategic Investment



Everybody Can't or Shouldn't be Top Quartile

Many utilities or regulators aspire to be top quartile... *most parents aspire for their children to be Q-1, too!*

- For there to be a Q-1, that means 75% of everybody else is is "worse". It is a forced ranking.
- Q-1 might be ***too good*** and waste of money for some circuits and systems.
- Q-1 may also be ***not good enough*** for others.

Reliability performance must be evaluated versus expectations on an individual circuit basis.

Other system-level comparisons are interesting, but should not be the final arbiter of performance measurement.