

SRP Voltage Sag Index Methodology – Experience and FAQs



Rao Thallam and Kris Koellner

IEEE PES P1564 TF Meeting
Las Vegas, 1/28/2003



IEEE PE Review – July 2001

- “While most utilities can quote reliability numbers; they cannot provide a measure of performance for the quality of power supply”

Don Volzka, PES President



Voltage Sag – Realities

- Magnitude varies during the event
- Sag different in Three Phases
- Impact of sag event is function of both voltage magnitude and duration
- Impact on equipment is exponential relationship to voltage
- Single index based on integral of voltage squared and duration – Convenient Index



Voltage Sag Energy, E_{VS}

$$E_{VS} = \left[1 - \int \frac{V_t^2}{V_{nom}^2} dt \right] \times 100$$



Sag Energy Index

- For a given location and period

$$\sum_i E_{VS_i}$$



System Average Sag Energy Index

$$\frac{\sum_{N} SEI}{N}$$



Voltage Sag Index Definitions

- SEI – Sag Energy Index
 - Analogous to “SAIDI”, takes into account voltage sag frequency, magnitude, and duration.
- SCI – Sag Count Index
 - Analogous to “SAIFI”, takes into account voltage sag frequency.
- SSI – Sag Severity Index
 - Analogous to “CAIDI”, takes into account voltage sag magnitude and duration.

$$SEI = SCI \times SSI = \sum_{month, monitor, etc} SE$$



Sample Sag Energy Calculations

If the phase energy values are 60, 90, and 90 and the duration of the event was 10 cycles (.166 seconds) the Sag Energy (SE) for that event would be:

$$SE = [(100 - 60) + (100 - 90) + (100 - 90)] \times [.166]$$

$$SE = [(40) + (10) + (10)] \times [.166]$$

$$SE = [60] \times [.166]$$

$$SE = 9.96$$

SE is only calculated for events up to 15 cycles (.25 seconds) so the worst case event would be an outage on all three phases for 15 cycles or longer. An outage is equivalent to phase energy values of 0, 0, and 0. The SE in this case would be:

$$SE = [(100 - 0) + (100 - 0) + (100 - 0)] \times [.25]$$

$$SE = [(100) + (100) + (100)] \times [.25]$$

$$SE = [300] \times [.25]$$

$$SE = 75$$



Sag Event Frequency Index

At a particular location and period
(month or year)

= Number of qualified sag events at that
location and period



System Sag Count Index

$$\text{SCI} = \frac{\text{Total Number of Qualified voltage Sag events}}{\text{Number of monitor locations}}$$

Note: By dividing with number of monitor locations,
data is normalized



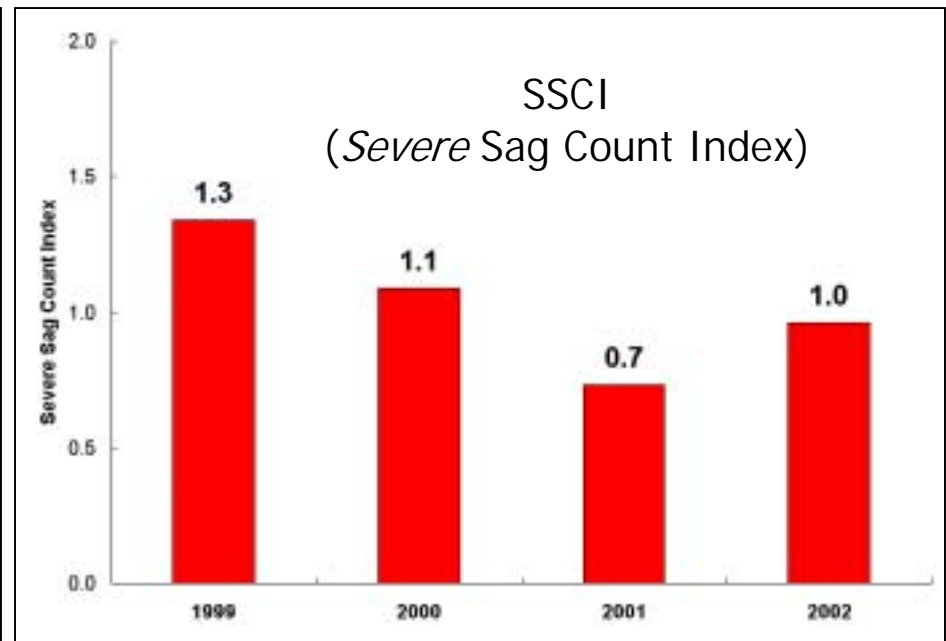
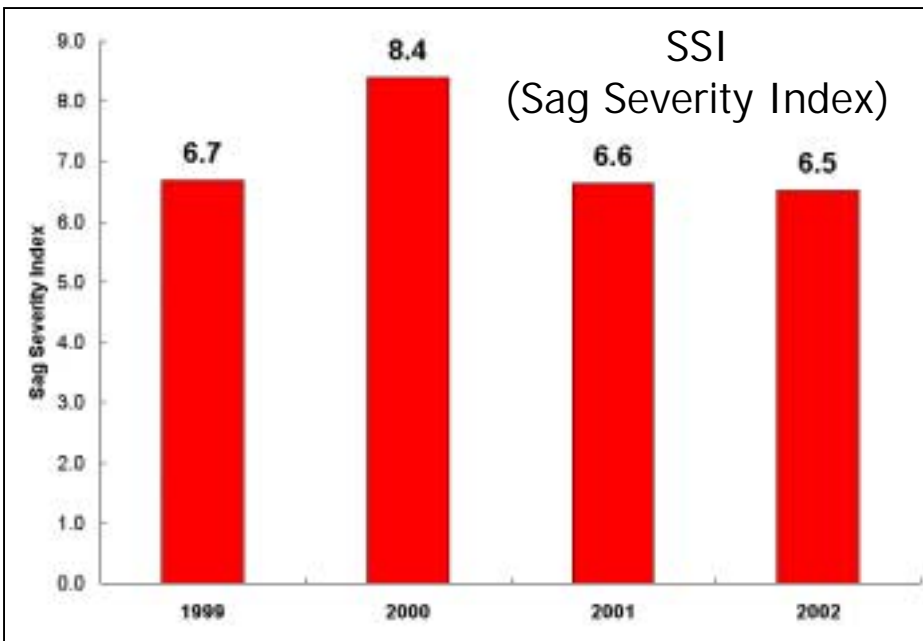
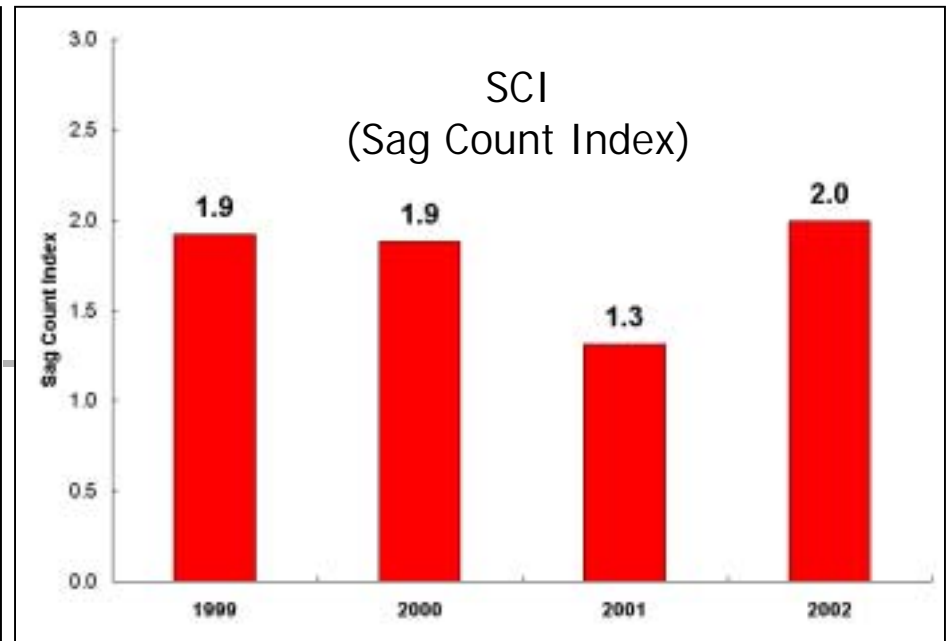
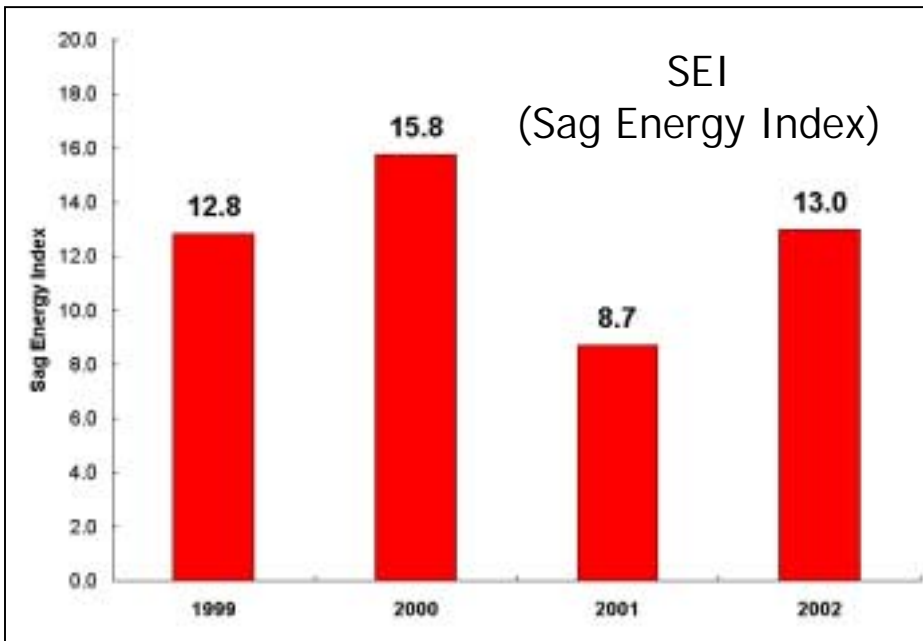
Qualifying Events

- Voltage Must be $< 90\%$
- Aggregation Time: 10 minutes
- Event Duration limited to 15 cycles
- Energy $> 100, = 100$
- Outages not included

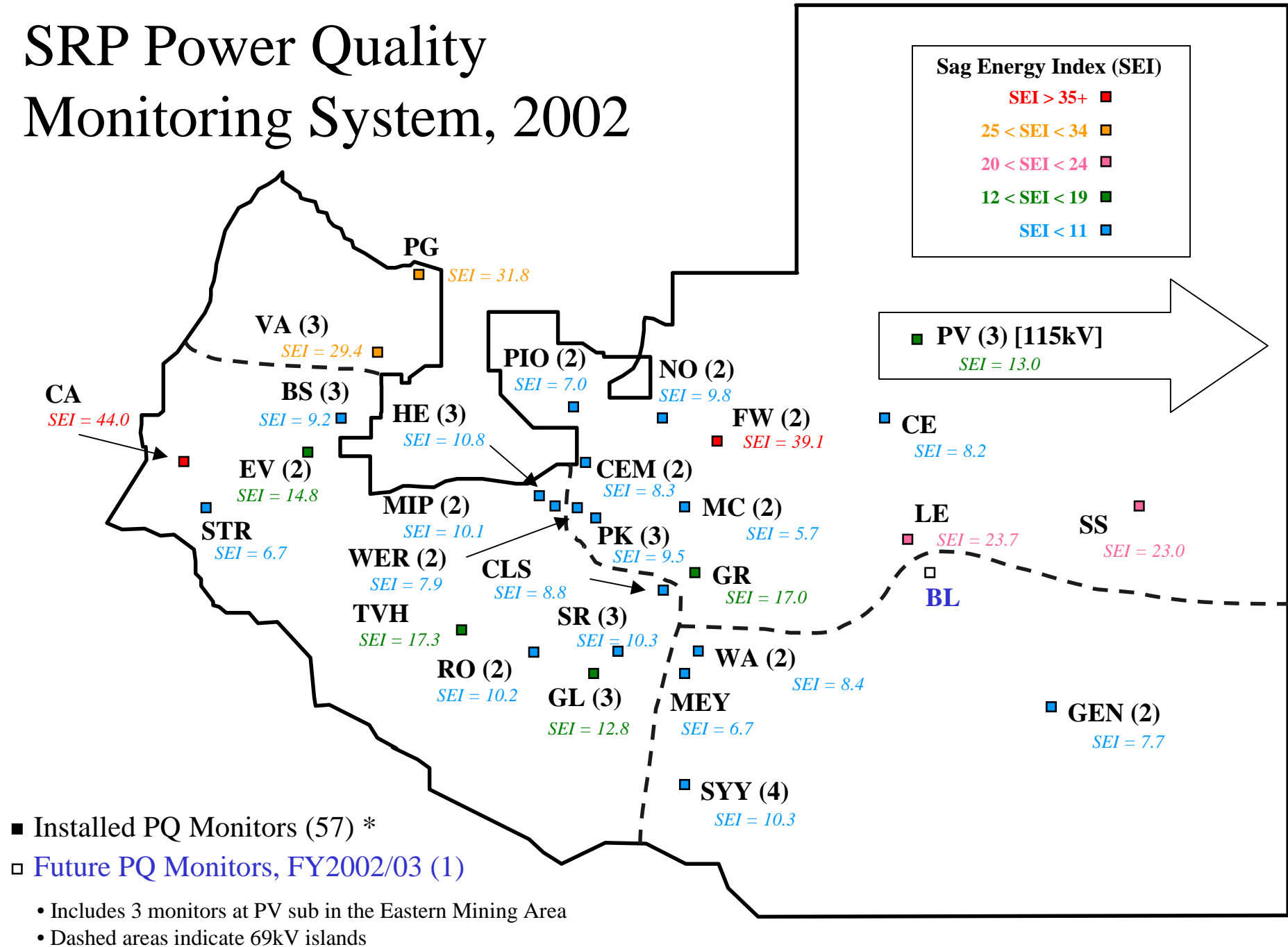


Data for 1999 - 2002

	1999	2000	2001	2002
No. of Monitors	25	36	43	57
Sag Events (<0.9)	609	926	747	1831
Events after aggregation	408	687	603	1233



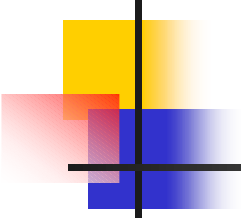
SRP Power Quality Monitoring System, 2002



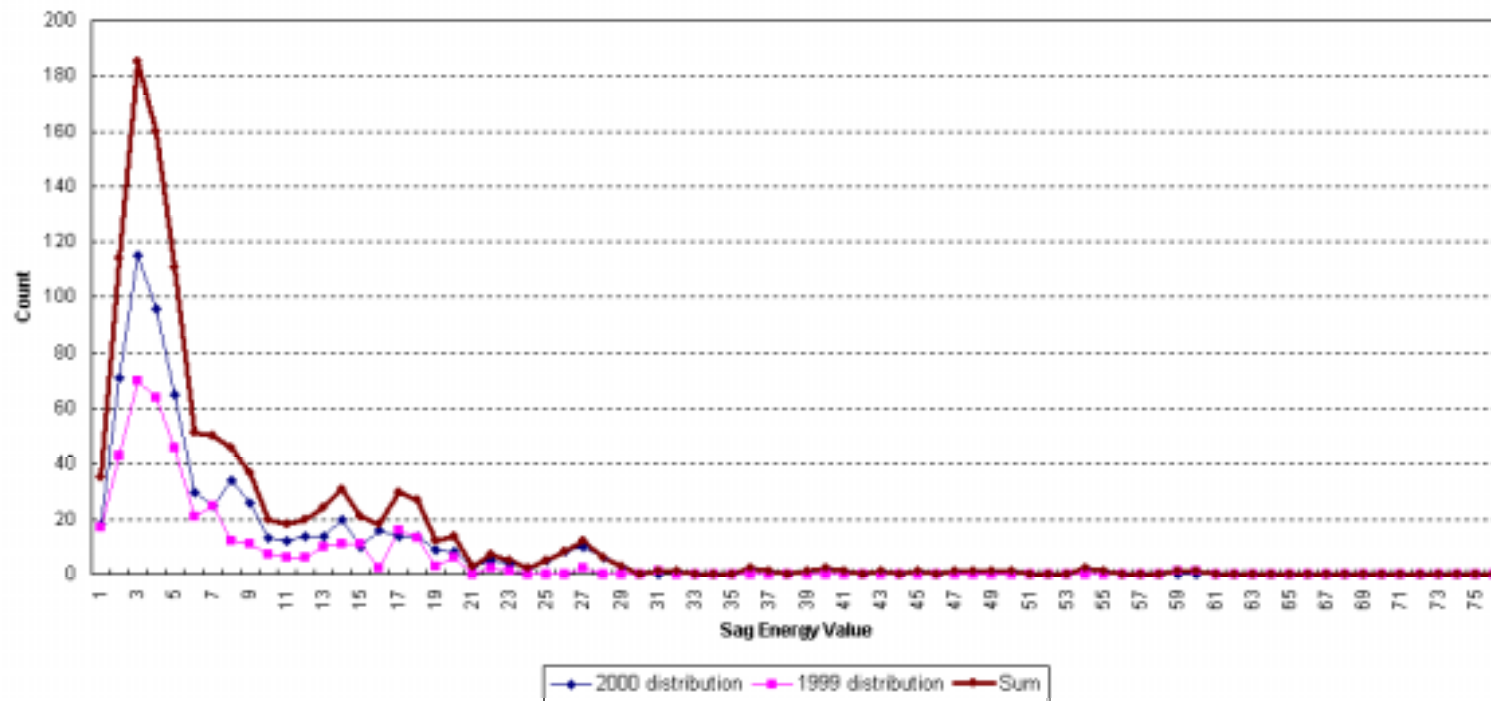


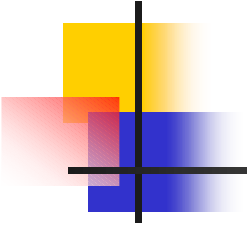
Average SEI (CY2000)

- Dedicated industrial substation = 12.9
- Residential 69kV substation = 18.9

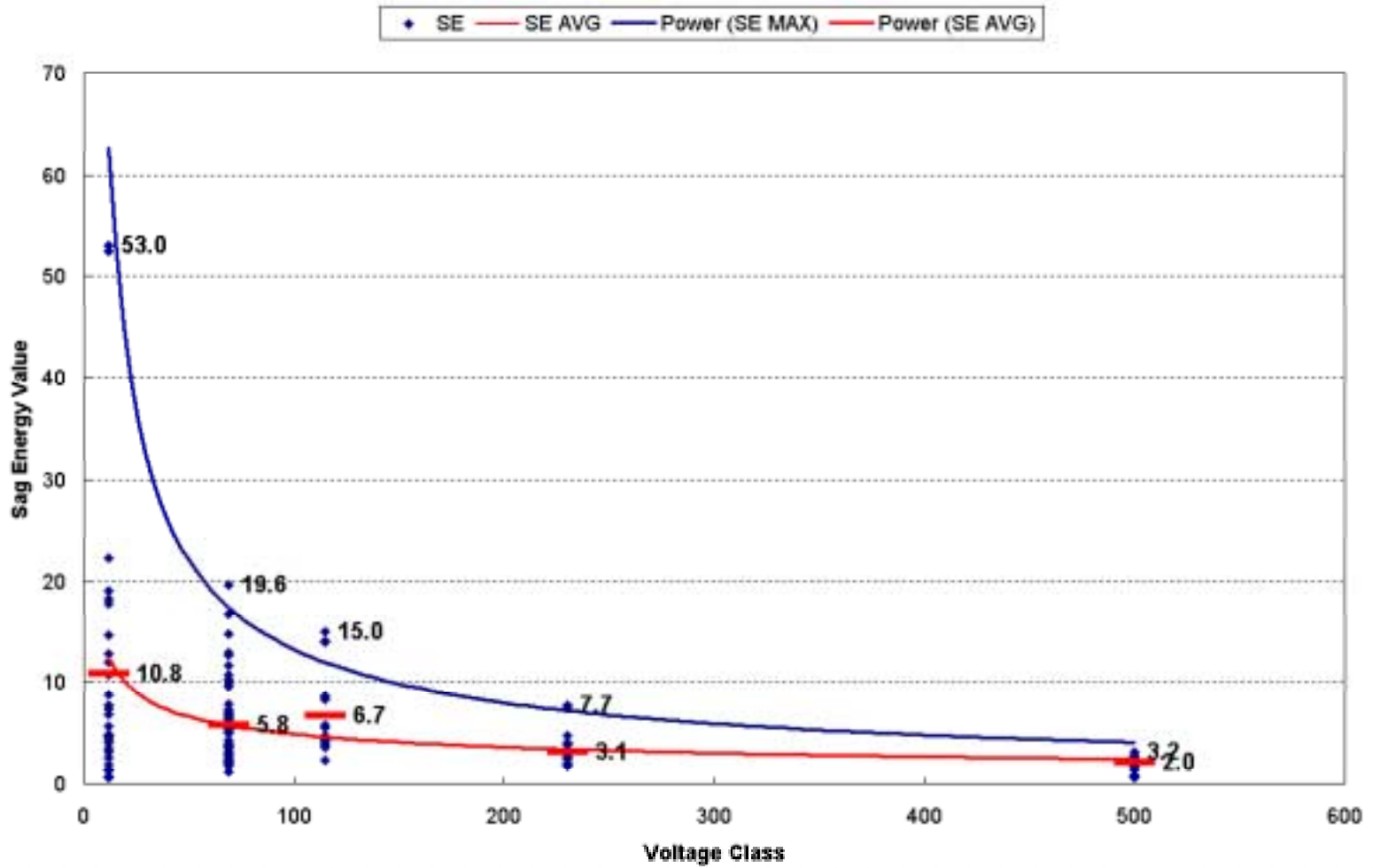


Distribution of Sag Energies for CY99, CY00
(0 = "0 to 1 bin", 1 = "1 to 2 bin", etc)



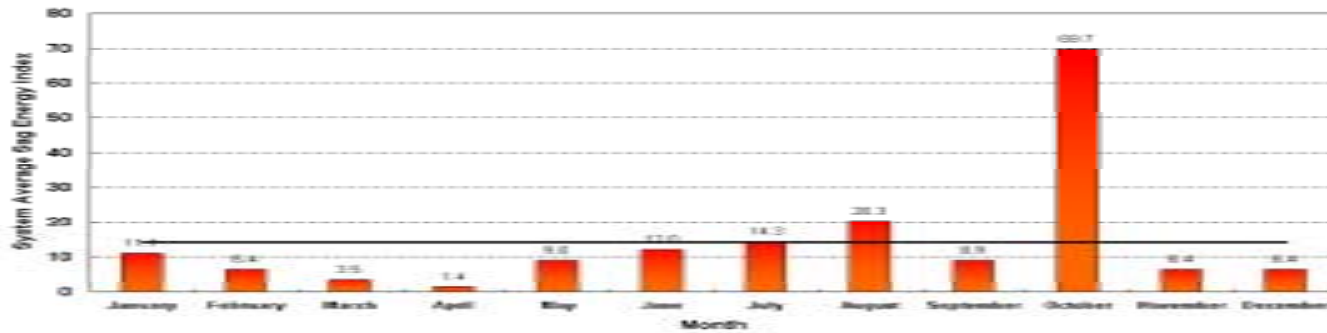


Distribution of Sag Energy Values vs. Voltage Class (CY2001 YTD)

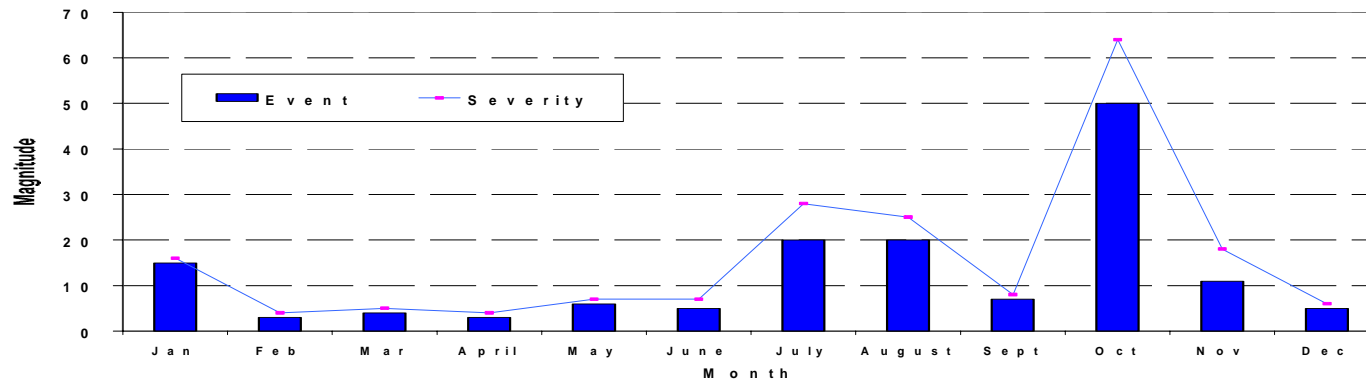


Correlation to C & I Customer Complaints

System Average Sag Energy Index (SEI) by Month, CY2000



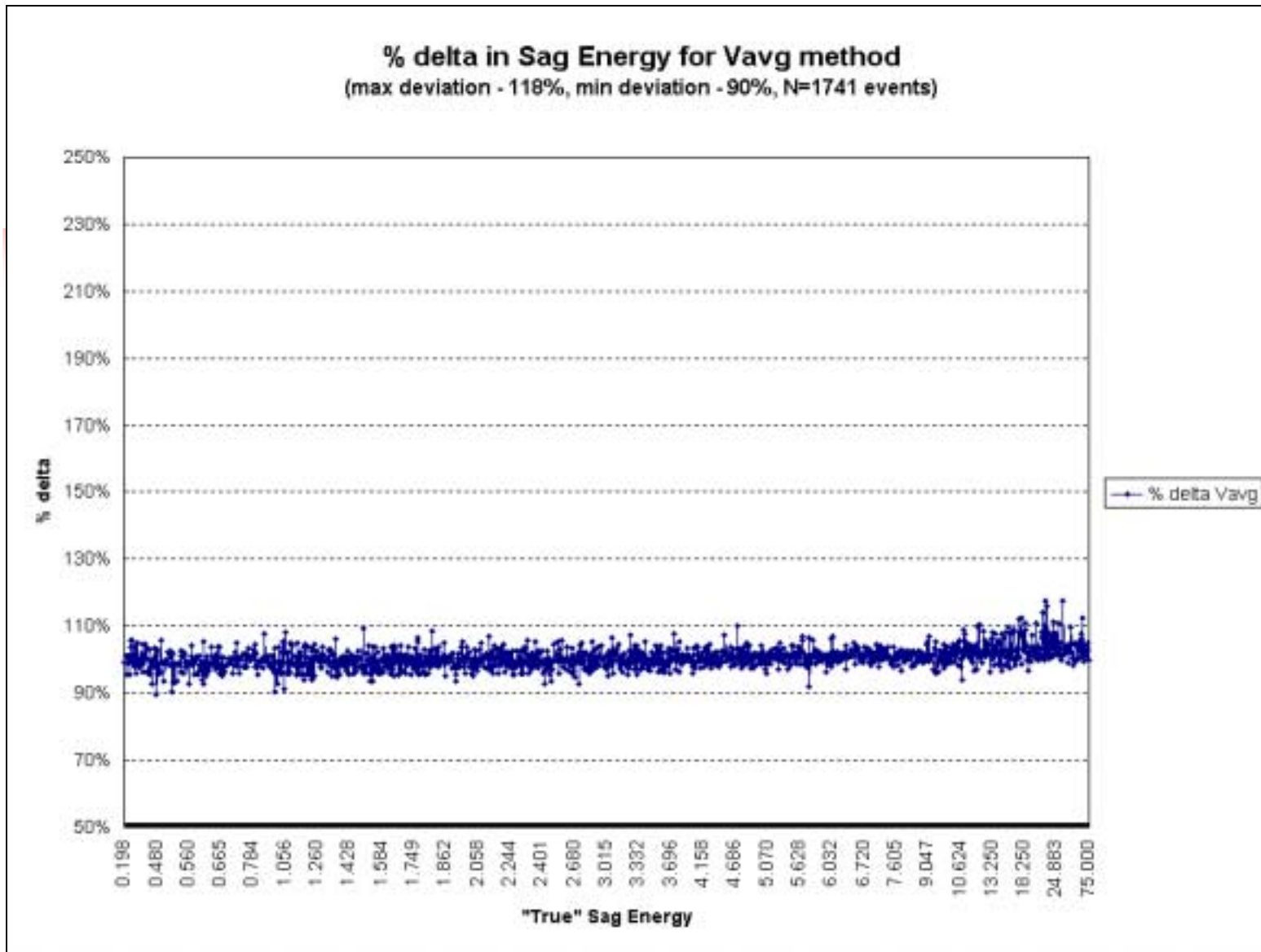
Large Industrial Customer Power Quality Issues, CY 2000





Sag Energy - FAQs

- Where do you get sag energy data for events?
- What if PML Monitors are not used?
 - Product of average sag voltage squared times duration is a good approximation for integration. Error < 2 to 3%
- Variation of number of monitor locations ?
Data is normalized
- Aggregation time ? 1 min or 10 min
- SRP LIC Satisfaction Index ?



- Results using V_{avg}^2/V_{nom}^2 rather than phase Energy
- Results are within +/- 10% towards the low end of the sag energy scale
- Maximum deviation at the upper end (longer, more severe events) 20



Conclusions

- SRP installed monitors at selected locations for benchmarking and quantify power quality
- 57 Monitors in 2002
- Power Quality Index based on sag energy developed
- Good correlation with customers' PQ concerns
- Results available for four years