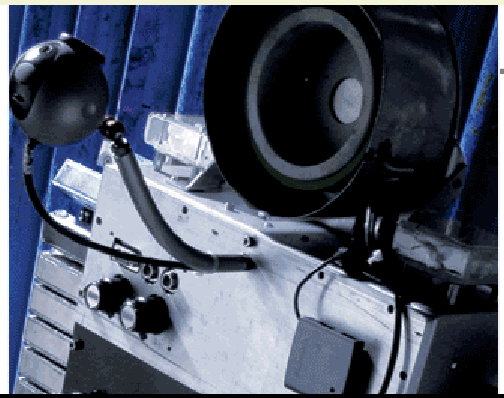
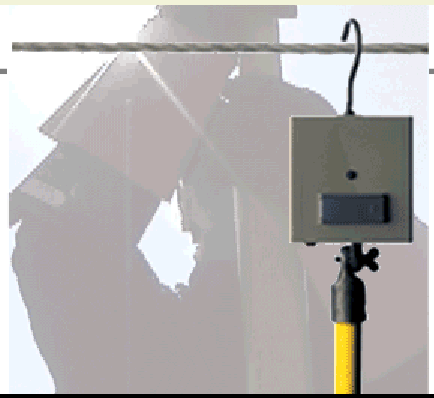
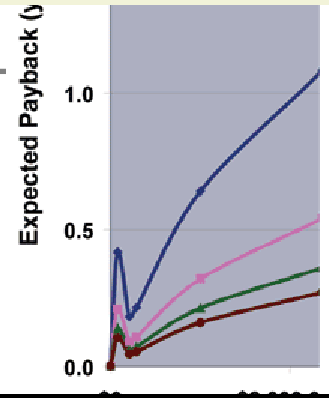
Providing innovative technologies...



...for the energy industry.

SF_6 Leak Detection with Low-Cost Wireless Sensors

Steve Willard P.E., Product Development Manager, Avistar Inc.

US EPA 4th International Conference on SF_6 and the Environment, Nov 28, 2006

Who is Avistar?

Avistar Inc. is the non-regulated subsidiary of PNM Resources (NYSE: PNM) and sister company to

- PNM (gas and electricity utility in New Mexico)
- Texas-New Mexico Power (electricity utility in New Mexico, electricity transmission and distribution company in Texas).
- First Choice Power (competitive retail electricity provider in Texas).

Avistar develops innovative technologies to address our sister utilities' operational challenges; commercializes those technologies that succeed

Avistar maintains multiple products available for license and/or sale:

- Reliadigm: reliability analysis software for any capital-intensive industry, such as power generation.
- AP-20: a phase-detection tool for utility line personnel and other field workers.
- Mutual Inductance Bridge (MIB): an NDT system for detecting boiler wall thinning in power plants and other process industries.
- Mosaic: a wireless technology platform for tracking SF_6 levels in breakers

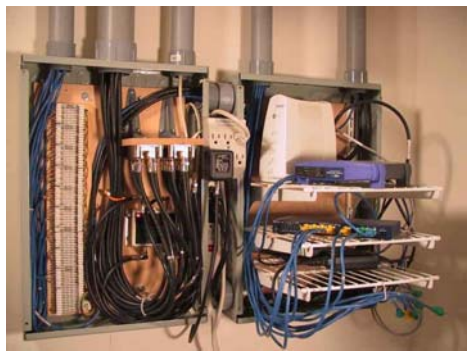
Not only are major assets antiquated their control systems are also out of date.

Circuit Breakers

- 21% of the fleet is 30-40 years old
- 17% is over 40 years
- Fleet includes numerous breaker types
- At > 69kV, majority are bulk oil breakers (50%) followed by dead tank SF6 breakers (36%)

Control Systems

- Provide minimal system condition information and utilize decades-old technology
- Data networks serving as an interface were not installed or spec'd to accommodate high bandwidths
- Not suitable for Asset Management based users



SF_6 Monitoring Needs – What Our Utilities Want

- Low cost
  - Current technologies afford
    - High cost leak detection
    - Medium cost monitoring
    - Lower cost monitoring needed
  - Retrofits
    - Installation costs can double the project cost
    - Use of wireless communication minimizes retrofit costs - *do not use SCADA*
- Predictive
  - O&M costs will be reduced by preventing over-time response to low pressure alarms
- Accurate
  - Current monitors only show larger leaks
  - Need to accurately accommodate for diurnal and annual pressure changes due to ambient temperature variations
- Environmental Sustainability
  - Although small overall GHG contribution SF_6 is deemed “low hanging fruit”

Utilize Available Technological Advances

- Wireless mesh networks
  - Low-cost radios or motes, and receptive gateways
  - Operate even in high EMF noise conditions
  - Each radio transmits, also receives and retransmits signals from neighbor radios
  - Self-configuring, self-healing
- Silicon based and micro-machined transducers
  - Increased accuracy
  - Decreased size
  - Decreased cost
- IEDs
  - Perform more analysis on the sensor chip
  - Sharp reduction in size and associated power consumption
- Algorithms
  - Advances in the software codes coupled with advances in chip technology
  - More analysis at the sensor, less on desktop

Solution is a low cost on-line SF_6 monitor

Outcome

- Detects and forecasts leak rates much more accurately
- Allows utility personnel to manage and maintain the SF_6 breakers more efficiently (scheduled maintenance is cheaper than unscheduled)
- Provides data source for Environmental Sustainability – “you can’t control what you don’t measure”

SF_6 Solution - Components

IEDs
- Perform much more analysis on the sensor chip
- Sharp reduction in chip size and power consumption
- Size reduction has already led to significant cost reductions
- Radio costs are expected to drop even more with increased manufacturing - $50 per sensor (mature OEM)
- Overall low power consumption extends battery life

Batteries
- Lithium Ion technology indicates life of 3-5 years for lower data sampling rates
- Integrated into the sensor package to allow easy replacement

Benefits of Wireless Communication

Wireless Communication

- Mesh Network
  - Utilizes 913MHz frequency
  - IEEE 902.15 standard
  - Much more viable than 2.4GHz in a substation environment
- Gateway web server
  - Can talk a variety of standard protocols over Ethernet or RS232
  - Working on DNP3
  - Future focus in IEC61850
- Security
  - Password & site certificate encrypted with SHA
- Outbound communications options
  - Wired – Ethernet
  - Wireless
    - Digital Cell Modem,
    - CDMA – 56kbs
    - ~$300 hardware, $60/month

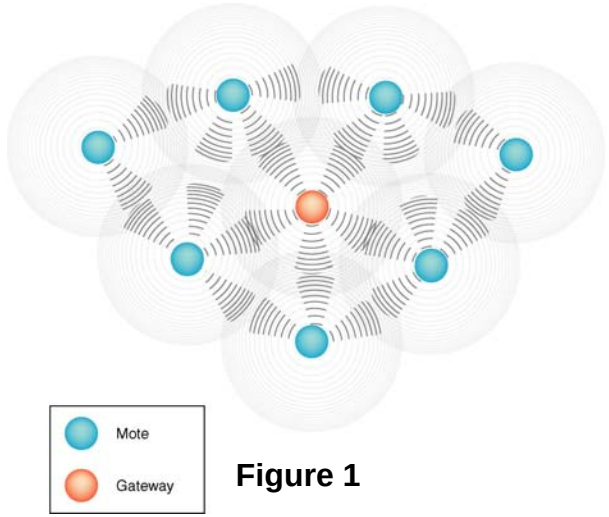
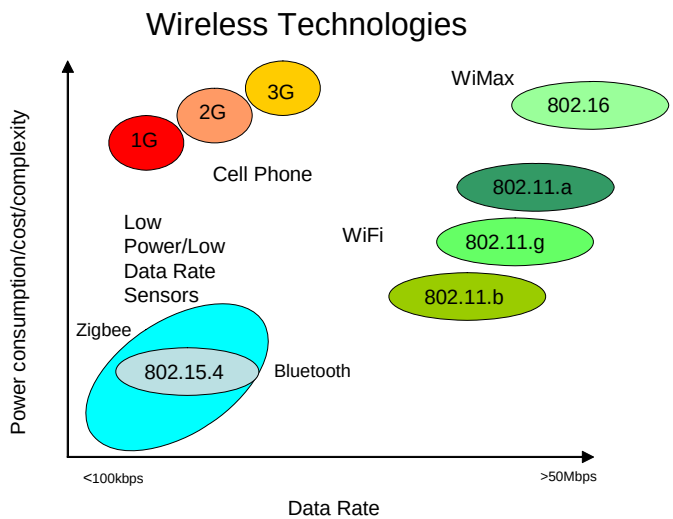


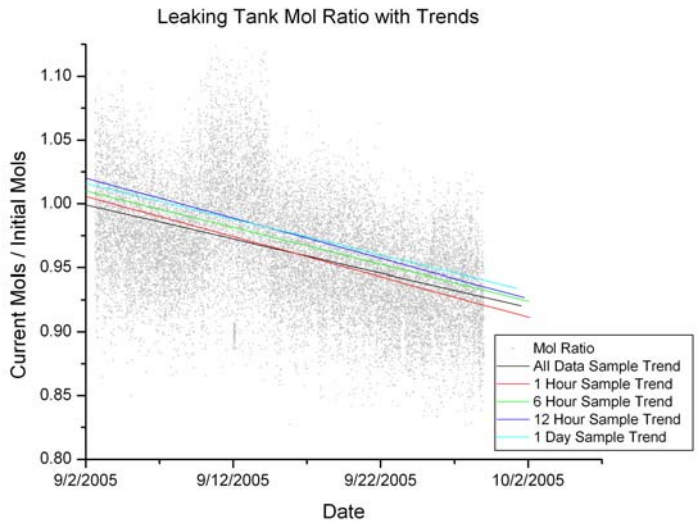
Figure 1

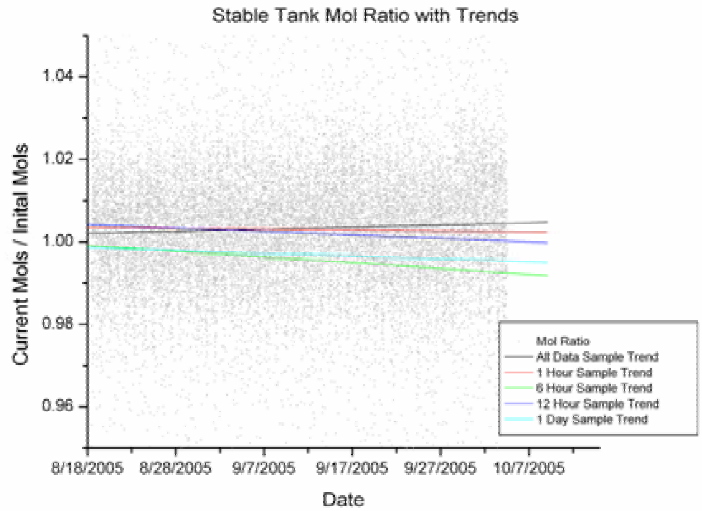


SF_6 Measurement Approach

Algorithms

- Measure accurately and accommodate for diurnal swings
- Employ ideal gas equation to determine molar content
- Require temperature and pressure of the gas at a given time
- Probing of interior of breaker for temperature not allowable
- Enhance sensitivity of pressure sensor by creating ratios of initial readings to current time reading
- Derive the initial molar content of the gas and compares ensuing molar content to the initial reading





SF_6 Measurement Approach

MOSAIC

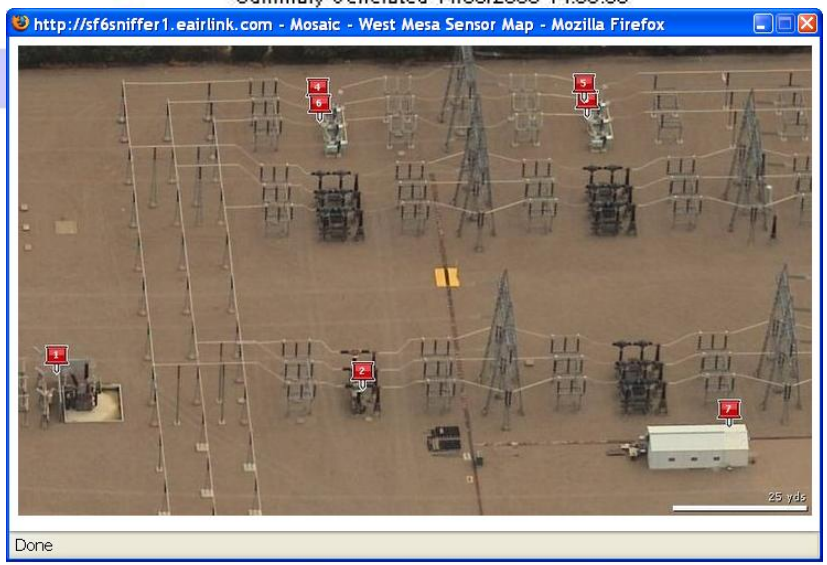
Admin | Contact | Help | Logout

Summary | Reports | Configuration | Settings | View Sensor Map

West Mesa > SF6 Monitoring > Summary | CSV Export

ID ▲	Name	Current Data Timestamp (MDT)	Expected Gas Alert Date	Gas Level	Leak Rate (monthly)	Battery Level	Sensor Status
1	Breaker 21382	11/08/2006 14:19:57	N/A	100.0% ✓	0.0% ✓	100.0% ✓	✓
2	Breaker 17982	11/08/2006 14:14:00	03/11/2007	100.0% ✓	6.2% !	100.0% ✓	✓
3	Breaker 23582-2	11/08/2006 14:37:04	N/A	100.0% ✓	0.0% ✓	100.0% ✓	✓
4	Breaker 22482-2	11/08/2006 13:36:06	N/A	100.0% ✓	0.0% ✓	100.0% ✓	✓
5	Breaker 23582-1	11/08/2006 13:52:46	N/A	100.0% ✓	1.4% ✓	100.0% ✓	✓
6	Breaker 22482-1	11/08/2006 13:35:21	N/A	99.2% ✓	0.0% ✓	100.0% ✓	✓

Summary Generated 11/08/2006 14:55:38



Quantifying the Numerous Benefits of Enhanced Monitoring

Decreased O&M costs

- Unscheduled repairs meant overtime, unscheduled dispatch
- Forecasted SF_6 levels allow for improved scheduling

Increased Reliability

- Outages due to leaks can be extremely costly from a whole system perspective

    N-x redundancy

Improved Environmental Sustainability

- Low cost of enhanced monitoring + high GHG factor of SF_6 = a compelling argument for better monitoring
- From a cap and trade perspective with CO_2 at $5/ton, the benefits can easily outweigh the costs of the sensor and gateway

Scalable communications platform –

- up to 200 low data rate sensors per gateway

O & M Savings – Limit Overtime Call Outs

Based on 2005-6 Data

Used actual leak rates

Segmented for leaking population of puffers and 2 pressure breakers

- Industry average = ~3% (from EPRI)

  Other sources indicate anywhere from <1% to 10%

- Avoidance of overtime call outs

	2 Pressure	Puffers
Total leak population	73%	17%
Payback*	.6 – 2.5 years	.7 – 4 years
Average Savings	**$329**	**$441**
Traditional method "Rolling the Truck"	**$500**	**$500**

*payback calculated when windshield time, 20% cost of gas ($6/lb) factored into savings and a cost of $500.

Reliability Impact – Understanding Critical Assets

Utility Perspective: for critical breakers 4 hour leakage outage can place a n-1 into a n-0 condition with backup reliance on aged breakers – greatly increased risk profile

EPRI Study: SF6 monitoring is a key issue in overall knowledge of CB Monitoring and Management

- Significant cost of MF

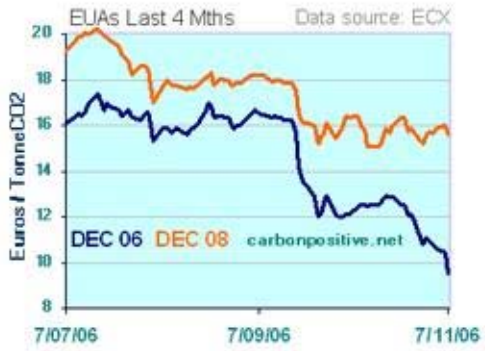
CIGRE Study – “Problems with the tightness of SF6 CBs (7.2% of MF and 39.6% mf) demand improvement of sealing systems.. .failures of the density supervision itself is responsible for 4% MF and 10.7% of mf.”

IEEE Study: FMEA of breakers can make case for CB monitoring

Environmental – Additional Savings

Current Driver - Stewardship
- SF6 targeted as a key component of Environmental Sustainability Efforts
- Scan of major utilities environmental web pages often feature SF6

Value of database for sensor data
- Establishes basis for cap & trade - data is:
  - Measurable
  - Quantifiable
  - Verifiable
  - Future Driver – Cap & Trade Allowances



Future Driver – Cap & Trade Allowances
- 1 lb leaked = 11 tons of CO2 equivalent
- $4-7/ton projected allowance – US (current $4.5 on Chicag
- US Regional Cap & Trade efforts being defined
  - SF6 listed as offset
  - Cap recently authorized by CA Energy Commission

Increased regulation on SF6 tracking foreseen in EU short term
- Containment regulations on “F gases” – Jan 06
- Recent price drop of CO2 in EU market for 1st phase allowances due to surplus
- 2nd phase prices holding steady

Environmental - Continued

Environmental

- Assume that a sensor allows for 20% of leak mitigation through better knowledge of gas content

  Apply $5/ton projected allowance to PNM breaker fleet

Entire Fleet

Utility Breaker	avg leak rate	avg lbs leaked	CO2 equiv tons	SF6 Monitor Mitigation	Unit Allowance @$5/ton
SF6 Puffer	1.5%	3	35	20%	$ 35.00
2 Pressure	6.9%	120	1429	20%	$ 1,429.47

Leaking Fleet Only

Utility Breaker	avg leak rate	avg lbs leaked	CO2 equiv tons	SF6 Monitor Mitigation	Unit Allowance @$5/ton
SF6 Puffer	20.4%	33	391	20%	$ 390.58
2 Pressure	10.0%	162	1940	20%	$ 1,940.00

SF_6 Solution is Scalable

Additional sensors under evaluation include:

- Transformer temperature sensors – to be aligned in conjunction with online DGA monitors
- SF_6 online monitoring for chemical degradation
- Air compressor run-time monitors for two pressure breakers
- Intrusion detection monitors for security purposes
- Traditional status point reporting for specific substation operating points that aren't currently monitored – using low-cost cell modems to transfer data into the utility LAN & other data environments

SF_6 Solution is Scalable

This path to enhanced monitoring allows for:

- Benefits that more clearly outweigh costs because they are identified on an individual rather than a collective analysis
- Incremental funding that allows for one automation step to be taken at a time while creating a cost efficiency for future steps
- Economic justification made because the criticality of each piece of substation equipment tends to be analyzed separately, not only as it relates to overall system reliability but as it relates to everyday O&M activities and environmental impact
- Implementation of appropriate technology through the use of the latest advances in robust wireless communication that functions in high EMF noise environments
- Focused management philosophy in which incremental solutions are presented with defensible cost-benefit ratios