

Goals / Problems Description

Goals

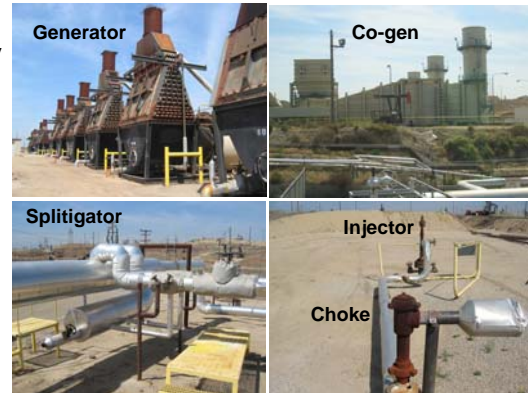
- Quickly detect, identify and localize anomalies that prevent planned delivery of steam or water to injection wells
- Continuously monitor diatomite reservoir changes due to waterflood

Problems

- Automatically differentiating between anomalies in steam and water pipeline networks such as blockage, leakage, outside force damage and equipment malfunction
- Detecting small changes in subsidence and uplift due to waterflood

Challenges

- Use inexpensive sensors, but provide reliable detection
- Automatically distinguish between problems and false alarms
- Providing continuous monitoring, quick report on problems, with little opex



Approaches for Anomaly Detection

Classification of anomalies

Events to detect		Where to put sensors	Reasons of events
Problems	Blockage	Splitigator, choke	Scale, left over after construction
	Leakage	Splitigator, junction	Pipeline corrosion, junction loose
	Outside force damage	Near roads or obstacles	Earthquake, stone
	Equipment breakdown	Generator, Splitigator, choke	Generator breakdown, Splitigator malfunction
False Alarms	Downhole pressure change	Injector	Vertical permeability, geological formation, heterogeneity
	Phase splitting at piping trees	Pipeline branches	difference in steam quality between upstream and downstream of branches
	Change in steam supply	Generator	Generator outage for scheduled maintenance
	Change in steam quality	Inlet of pipeline, Before and after Splitigator, Pipeline elevation	2-phase transient property of steam, Pipeline elevation, generator turns on
	Sensor noise and faults	A pair of close-by sensors in the middle of pipeline	Inaccurate and unreliable thermometer, pressure meter
	Environmental reasons	A pair of close-by sensors in the middle of pipeline	Ambient temperature

Why difficult?

- Low-cost sensors can be unreliable and inaccurate
- False alarms can be mistaken for real anomalies
- Must understand topological effects of pipeline
- Must understand transients in steam and waterflood

Overall approaches

- Utilize multi-modal sensing, multi-node collaboration
- Exploit spatial and temporal correlations in multiple sensors, e.g., triggered by the same event
- Create **rule-based decision tree algorithm** running on distributed sensors

Anomaly detection algorithm

Single-Node Processing

- Sensor readings validation
- Noise reduction
- Event detection – *do I see a problem?*

Multi-Node Collaboration

- Multi-sensor validation – *faulty sensors?*
- Problem identification – *anomaly or false alarm?*
- Problem localization – *where is problem origin?*

Tasks for Lost Hills Grant Challenge

Task 1: continuously monitor surface elevation changes with differential GPS sensors

- Understand relationship between material balance and degree of subsidence/uplift
- Help understand water distribution in diatomite reservoir
- Current InSAR system takes a snapshot every 24 days
- Use distributed GPS sensors for continuous monitoring

Task 2: evaluate availability and potential use of downhole sensors

- Downhole sensing provide more information, but it is a very hard problem

Task 3: detect anomalies in waterflood distribution system

- Quickly identify problems that cause out-of-target injection
- Leakage, plugging, equipment malfunction, etc.
- Goal is to help maintain oil production by quickly fixing detected problems
- Help to reduce maintenance workload
- Operators only focus on real problems, not false alarms
- Apply steamflood monitoring results to waterflood system

Future plan

- Evaluate anomaly detection algorithm in simulation (expect to use *Dynsim*)
- Evaluate where and how to apply anomaly detection to the waterflood system
- Evaluate availability of high-precision differential GPS sensors and how to deploy them in Lost Hills
- Evaluate availability of downhole sensors and their potential usage at Lost Hills

Publications:

- SunHee Yoon, Wei Ye, John Heidemann, and Brian Littlefield, "Timely, Reliable, and Accurate Steamflood Monitoring Using Wireless Sensor Networks," To be submitted to SPE Annual Technical Conference.
- John Heidemann and Wei Ye. Towards Full-disclosure: Broadening Access to SCADA Data to Improve Safety, Reliability, and Security. Proc. National Workshop on Beyond SCADA, November, 2006.
- Wei Ye and John Heidemann, "Enabling Interoperability and Extensibility of Future SCADA Systems," Proc. National Workshop on Beyond SCADA: Networked Embedded Control for Critical Physical Infrastructures, Pittsburgh, PA, USA, November, 2006.
- Wei Ye, Fabio Silva, and John Heidemann, "Ultra-Low Duty Cycle MAC with Scheduled Channel Polling," In Proceedings of the 4th ACM Conference on Embedded Networked Sensor Systems (SenSys), Boulder, Colorado, USA, November, 2006.