Automated Well Field Control

SWANA Webinar
April 27th, 2016

Presented by: Andrew Campanella
Shaun Bamforth

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About the presenters

ANDY CAMPANELLA
- B.S. Electrical Engineering and Computer Science at MIT
- M.S. in System Design and Management at MIT
- Founder and CEO of Loci Controls, Inc.
- Inventor on 35 US patents, dozens of applications
- Expert in control systems, power systems and electronics

SHAUN BAMFORTH, PE
- B.S. Civil Engineering at Rensselaer Polytechnic Institute
- M.S. Business Administration at MIT
- VP, Marketing & Sales at Loci
- Former Engineering Consultant, LEED AP
Outline

- Typical Landfill Gas Collection Process
- Remote Monitoring and Automatic Control
- Technical Discussion
- Case Study – Automated Well Field Tuning
- Other Lessons Learned
Typical gas collection system

1. Trash generates methane gas
2. Gas collected from wells
3. Gas burned to generate electricity
4. Electricity sold to the grid

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Drawbacks of typical collection system

- Manual surveys of well field are very labor intensive
- Infrequent measurement & tuning due to time/effort required
- Well adjustments are an art rather than a science
Potential for system automation

• More Gas = More Revenue

• Reduce Odor Risk by Eliminating Fugitive Emissions

• Labor Savings – More Efficient Use of Technician Time
Automated well field control system

**MONITOR**
real-time, wireless measurement of landfill gas production

**CONTROL**
remote, automatic adjustments to individual extraction points

**OPTIMIZE**
maximize system performance with custom tuning algorithms

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Installed device

- Manual valve (bypassed)
- 2” Flexible hose with pipe clamps
- Standard flexible reducing coupling
- Gas extraction well
- Device mounts to vacuum riser

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Integrated measurement and control

- Gas Composition: % CH$_4$, CO$_2$ & O$_2$
- Temperature
- Flow rate
- Well Static Pressure
- System Vacuum

**MONITOR**
real-time, wireless measurement of landfill gas production

**CONTROL**
remote, automatic adjustments to individual extraction points

- Remotely actuated valve
- Continuous resolution, 0-100% range
- Variable control interval, step size

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• Set custom alarms
• Instantly identify problems
• View real time data
• Energy analytics
Technical Discussion Outline

- Gas generation vs. gas extraction
- Rate imbalances
- Single well tuning
- Well to well interactions
- System optimization
- Questions
Gas generation vs. extraction

Gas Extraction Rate: \( \frac{LFG_E}{t} \)

Gas Generation Rate: \( \frac{LFG_G}{t} \)

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Factors impacting generation

Gas Generation Rate:

\[ \frac{LFG}{t} \frac{G}{f(x_1, x_2, \ldots)} \]

- \( x_1 \) : Temperature
- \( x_2 \) : Moisture content
- \( x_3 \) : Oxygen levels
- \( x_4 \) : Mass of organics
- \( x_5 \) : Age of waste
Factors impacting extraction

Gas Extraction Rate (flow): 

\[ \frac{LFG_E}{t} = f(y_1, y_2, \ldots) \]

- \( y_1 \): Barometric pressure
- \( y_2 \): Well static pressure
- \( y_3 \): Perforated pipe area
- \( y_4 \): Piping diameter
- \( y_5 \): Subsurface gas migration
- \( y_6 \): Surface cover permeability

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Technical Discussion Outline

- Gas generation vs. gas extraction
- Rate imbalances
- Single well tuning
- Well to well interactions
- System optimization
- Questions

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Rate imbalance, pt. 1

Gas Extraction $< \frac{LFG_E}{t}$Gas Generation $< \frac{LFG_G}{t}$

**Effect**
- Buildup and eventual leak of LFG into atmosphere
- Surface oxidation of methane passing through cover soil
- Odors and environmental contamination risk

Emissions = lost revenue

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Rate imbalance, pt. 2

**Gas Extraction** < **Gas Generation**

**Gas quality**
- Rising CH$_4$ and CO$_2$ concentrations
- Approaching ~60/40 at steady state
- Decreasing O$_2$ and balance gas
- Approaching 0

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Rate imbalance, pt. 3

Gas Extraction > Gas Generation

\[ \frac{LFG_E}{t} > \frac{LFG_G}{t} \]

**Effect**

- Oxygen intrusion -> aerobic digestion!
- Poor gas quality
- Underground fire/reaction risk
- Loss of CH4 generation (poor anaerobic conditions)

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Rate imbalance, pt. 4

Gas Extraction > Gas Generation

Gas quality

- Falling CH₄ and CO₂ concentrations
- Approaching ~0 at steady state
- Rising O₂ and balance gas
- > 4% O₂ is cause for concern
Technical Discussion Outline

- Gas generation vs. gas extraction
- Rate imbalances
  - Single well tuning
- Well to well interactions
- System optimization
- Questions

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Control system objective

Gas Extraction = Gas Generation

Successful well tuning:

- Stable gas quality
- Minimized emissions/odors
- Long term maximization of methane generation
- Low risk of underground thermal runaway

\[
\frac{LFG_E}{t} = \frac{LFG_G}{t}
\]

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What’s wrong with this picture?
Technical Discussion Outline

- Gas generation vs. gas extraction
- Rate imbalances
- Single well tuning
- Well to well interactions
- System optimization
- Questions
Well to well interactions

\[
\frac{LFG_A}{t} f(x_1, x_2, \ldots)
\]

\[
\frac{LFG_B}{t} f(x_1, x_2, \ldots)
\]
Well to well interactions

\[ \frac{LFG_A}{t} \quad f(x_1, x_2, \ldots) \]

\[ \frac{LFG_B}{t} \quad f(x_1, x_2, \ldots) \]
Well to well interactions

Influence of Well B on A

\[
\frac{LFG_A}{t} \cdot f(x_1, x_2, \ldots) + f(LFG_B)
\]

Influence of Well A on B

\[
\frac{LFG_B}{t} \cdot f(x_1, x_2, \ldots) + f(LFG_A)
\]
Well to well interactions

Well B must first overcome excess vacuum from A and C!
Well to well interactions

Better configuration from a system perspective!
Technical Discussion Outline

- Gas generation vs. gas extraction
- Rate imbalances
- Single well tuning
- Well to well interactions
- Well field tuning
- Questions
Flow at 50% CH4 (SCFM)

Total Flow: 334
Total Flow: 334
Total Flow: 342
Push extraction towards "dead" wells

Total Flow: 375
Total Flow: 378
Total Flow: 425
Total Flow: 479
Technical Discussion Outline

- Gas generation vs. gas extraction
- Rate imbalances
- Single well tuning
- Well to well interactions
- Well *field* tuning
- Questions
Estimated Value of Automatic Control

How much additional gas can we produce through the use of automatic control?
  - Modeled vs. Empirical

What is the value of an incremental unit of landfill gas?
  - Economics of Power Sales (PPA, DAM, Spot, etc.)
  - Is There Available Capacity?

What is the potential value of a site-wide installation?
  - Number of wells to install automated control
Increased Gas Production

Average Increase (per site) = 102.63 SCFM
Average Increase (per installed well) = 10.88 SCFM

Note – All production values corrected to 50% CH4
Value of Incremental Gas Production

1. Incremental Monthly Gas Volume = 43,800 SCF
   \(1\text{scfm} \times 60\text{min/hr} \times 24\text{hr/day} \times 365\text{days}/12\text{months}\)

2. Energy Content of Incremental Landfill Gas = 22,184,700 BTU / Month
   \(50\% \times 43,800\text{scf} \times 506.5\text{BTU/scf}\)

3. Power Produced by Incremental Landfill Gas = 1.896 MWh / Month
   \(22,184,700\text{BTU} \times 1\text{kWh/11,700BTU} \times 1000\text{kWh/1MWh}\)

4. Incremental Value of 1SCFM Landfill Gas = $190
   (Assumes Electricity + REC = $100/MWh)

<table>
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<th>Number of Installed Wells</th>
<th>Increase in LFG Flow (SCFM) @ 50% Methane</th>
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<td>10</td>
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Value of Site-Wide Installation

Site Information
Total Wells = 100
Wells with Automatic Control = 20
Estimated Production Increase = 20 wells * 10.88 scfm = 217.6 scfm
Value of Power Sale + REC Sale = $100 / MWh

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Total Monthly Revenue Increase = $41,260
Potential for system automation

• Improved LFG collection efficiency
• More gas = more LFGTE revenue
• Odor control by reducing fugitive emissions
• Labor savings – more efficient use of technician time
THANK YOU FOR JOINING OUR WEBINAR!

SWANA Webinar – April 27th, 2016

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