OKLAHOMA POWER AND COMMUNICATIONS ASSOCIATION 2017 FALL MEETING
OCTOBER 9TH – 10TH, 2017
WYNDHAM GARDEN HOTEL – OKC AIRPORT

Enhanced Predictive-Based Maintenance Strategy

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Presentation Outline

- PdM Strategy Overview - patented RF Technology combined with IR
- Use of Predictive Methodologies to refine Business Case Strategies
- Targeted Field Work – RF, Ultrasonic, IR, and Visual Methods
- Recommendations for an Integrated Reliability Program
- Case Study & Results of Pilot and Multiyear Program 2015 thru 2017

PdM Strategy Overview - patented RF Technology combined with IR

Predictive-Based Maintenance (PdM)

A **reliability strategy** that assesses the condition of equipment **while in service** to determine the appropriate maintenance operation to avoid interruption or equipment failure:

1. **Proactive Approach**
   - Transition from reactive restoration
   - Utilizing two technologies Exacter RF and Davey Infrared

2. **Targeted**
   - Assess where Equipment related issues occur
   - Critical Infrastructure (serves the greatest # of customers)

3. **Measurable**
   - **Pre-Assessment:** Identify opportunity for improvement
   - **Assessment:** Validate opportunity for improvement
   - **Post-Assessment:** Track progress towards achieving goals

PdM Strategy Overview - patented RF Technology combined with IR

Conditions: PD/EMI Phenomena

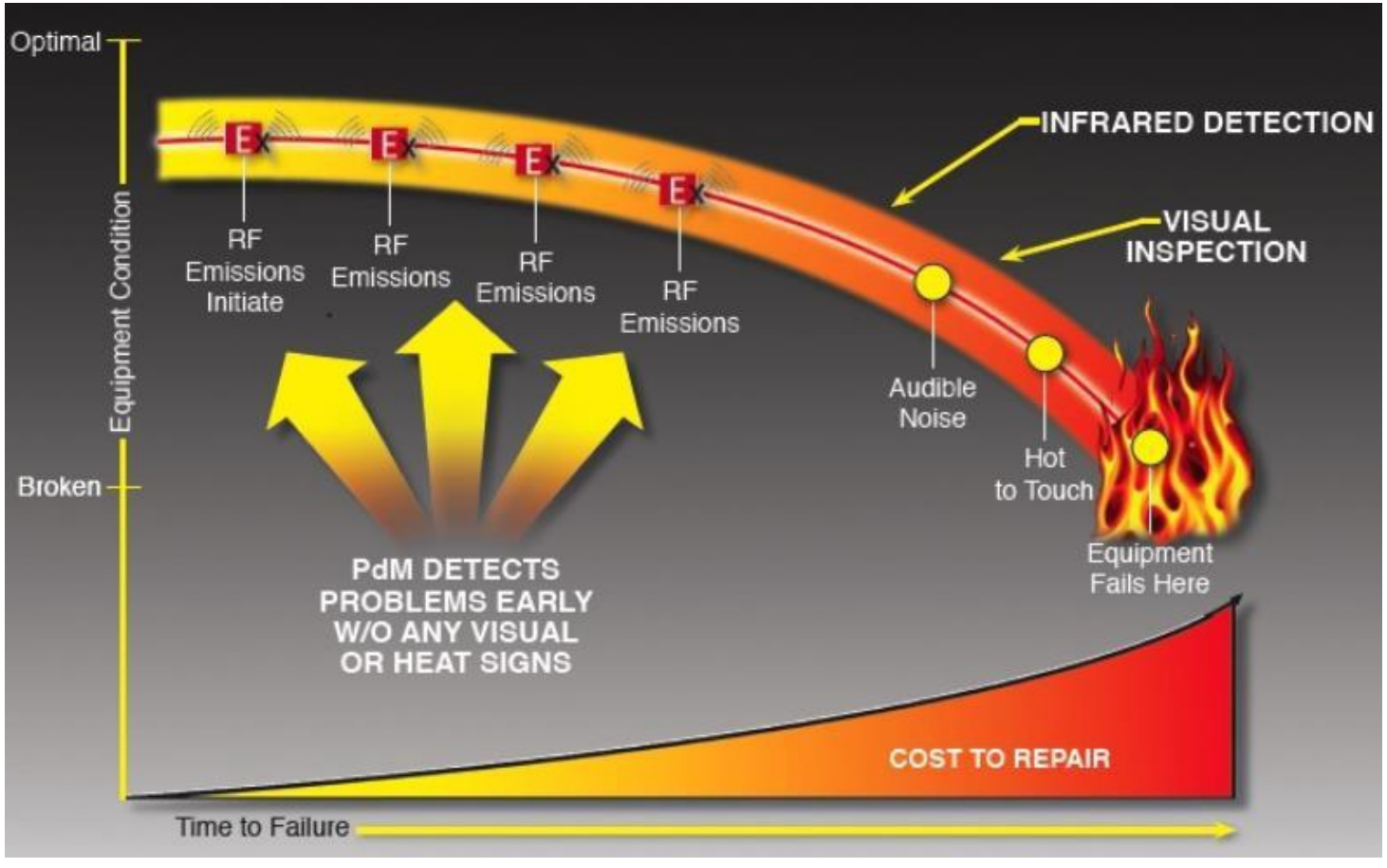
"Arc emissions are the primary characteristic of electrical equipment failure."

Dr. Stephen Sebo
The Ohio State University High Voltage Laboratory

- **Partial Discharge (PD) and Electromagnetic Interference (EMI) are leading indicators of early stage failure in electrical components**
  - Arcing
  - Tracking
  - Leaking
- **PD and EMI emissions are present when electrical components are contaminated, degraded, or in a failed state**
  - Components no longer maintain insulating and mechanical properties
- **Outage can occur as a result of equipment failure**

PdM Strategy Overview - patented RF Technology combined with IR

PdM Conditions Provide Advanced Warning



Data Analysis: Historical Interruption Data

PEC provided the most recent 12 months of interruption data

August 1, 2014 – July 31, 2015

Interruption Data: Most Recent 12 months			
Outage Cause	**# of Interruptions**	**CMI**	**% of CMI**
Equipment	784	1,539,744	14%
Lightning	2,377	3,107,415	29%
Total	4,864	10,768,348	100%

Use of Predictive Methodologies to refine Business Case Strategies

Assessment: District Analysis

POWER OF COMMUNITY PEDERNALES ELECTRIC COOPERATIVE — Equipment CMI by Service Division						
Service Division	**Feeder Customers**	**OH Miles**	**OH 3-Phase**	**Equipment CMI**	**EQ CMI / OH Mi**	**Customer / OH Mi**
Bertram	14,251	1,984.7	350.6	41,478	20.90	7.2
Canyon Lake	32,521	1,894.0	427.4	131,509	69.43	17.2
Cedar Park	**66,928**	**695.4**	**281.1**	**172,440**	**247.97**	**96.2**
Junction	8,319	3,780.3	519.2	219,586	58.09	2.2
Kyle	41,017	1,347.8	385.2	178,675	132.57	30.4
Liberty Hill	**30,661**	**1,233.0**	**385.1**	**572,035**	**463.93**	**24.9**
Marble Falls	32,139	2,526.6	543.5	40,268	15.94	12.7
Oak Hill	43,777	1,493.5	370.1	200,186	134.04	29.3
Total	**269,613**	**14,955.3**	**3,262.2**	**1,556,177**	**104.06**	**18.0**

Use of Predictive Methodologies to refine Business Case Strategies

The Same PdM Strategy = Solutions to Many Different Problems

• Improve Worst Performing Circuits	• Attack Unknown Line Operations
• Reduce CMI	• Replace Specific Equipment Types
• Smart Grid Hardening	• Resilient AMI Systems
• Delay Line Rebuilds	• Reduce Customer Complaints
• Reduce SAIDI, SAIFI	• Target Areas For Improvement
• Pre-and-Post Storm Analytics	• Remove Contaminated Insulators
• Replace Faulty Arresters	• Identify Worst Performing Areas

Targeted Field Work using RF, Ultrasonic, IR, and Visual Methods

Data Acquisition & Discrimination

RF emissions from arcing (deteriorated) electrical components

Exacter sensor in vehicle/aircraft collects the signals and then discriminates and GPS locates arcing, tracking and leaking electrical components

Data Analysis

Data analyzed for severity, persistence and prevalence, enabling:

- Discriminate & correlate RF emissions
- Identify exact location of failing component

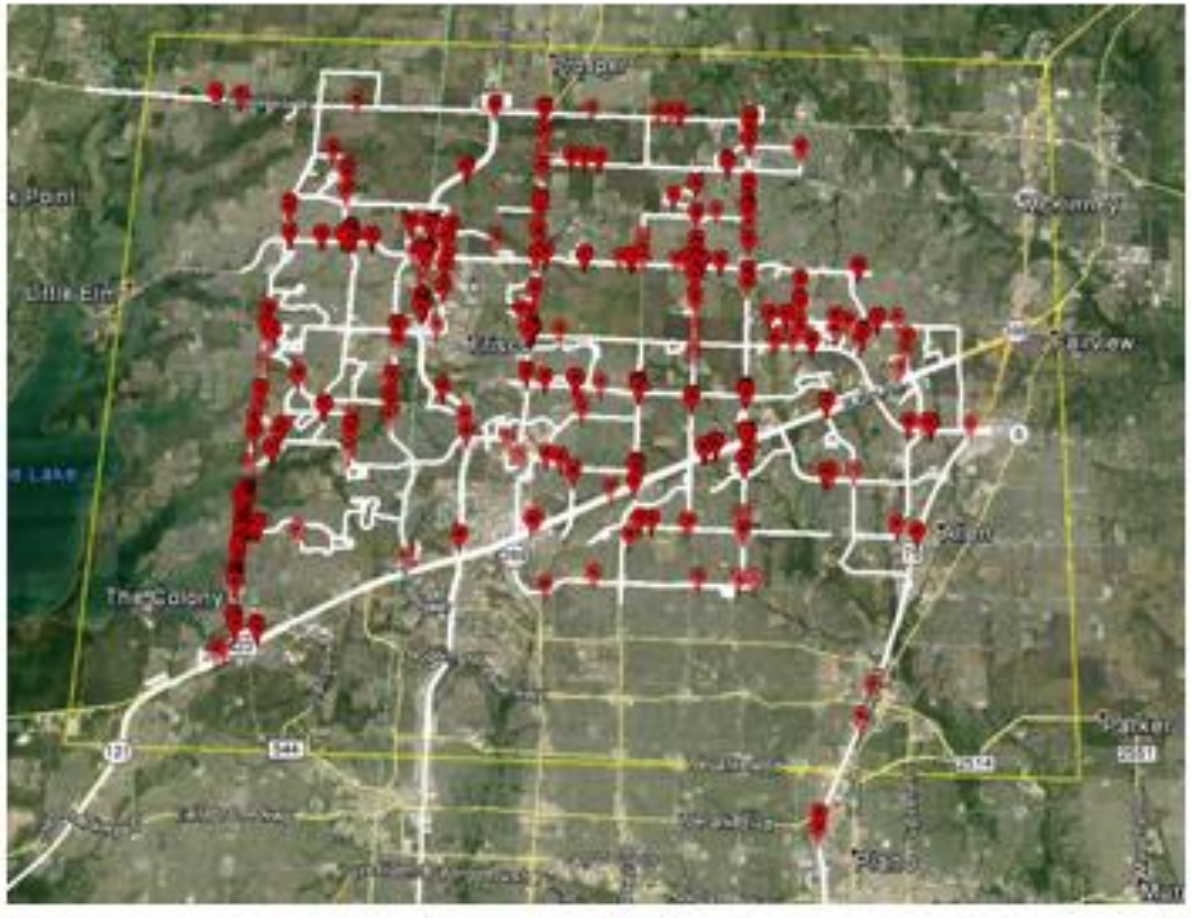
Precise GPS coordinates and relevant condition-data transmitted to servers for final statistical geospatial analysis

Ultrasonic Field Confirmation

Exacter Field Engineer confirms & pinpoints component responsible for condition

Targeted Field Work using RF, Ultrasonic, IR, and Visual Methods

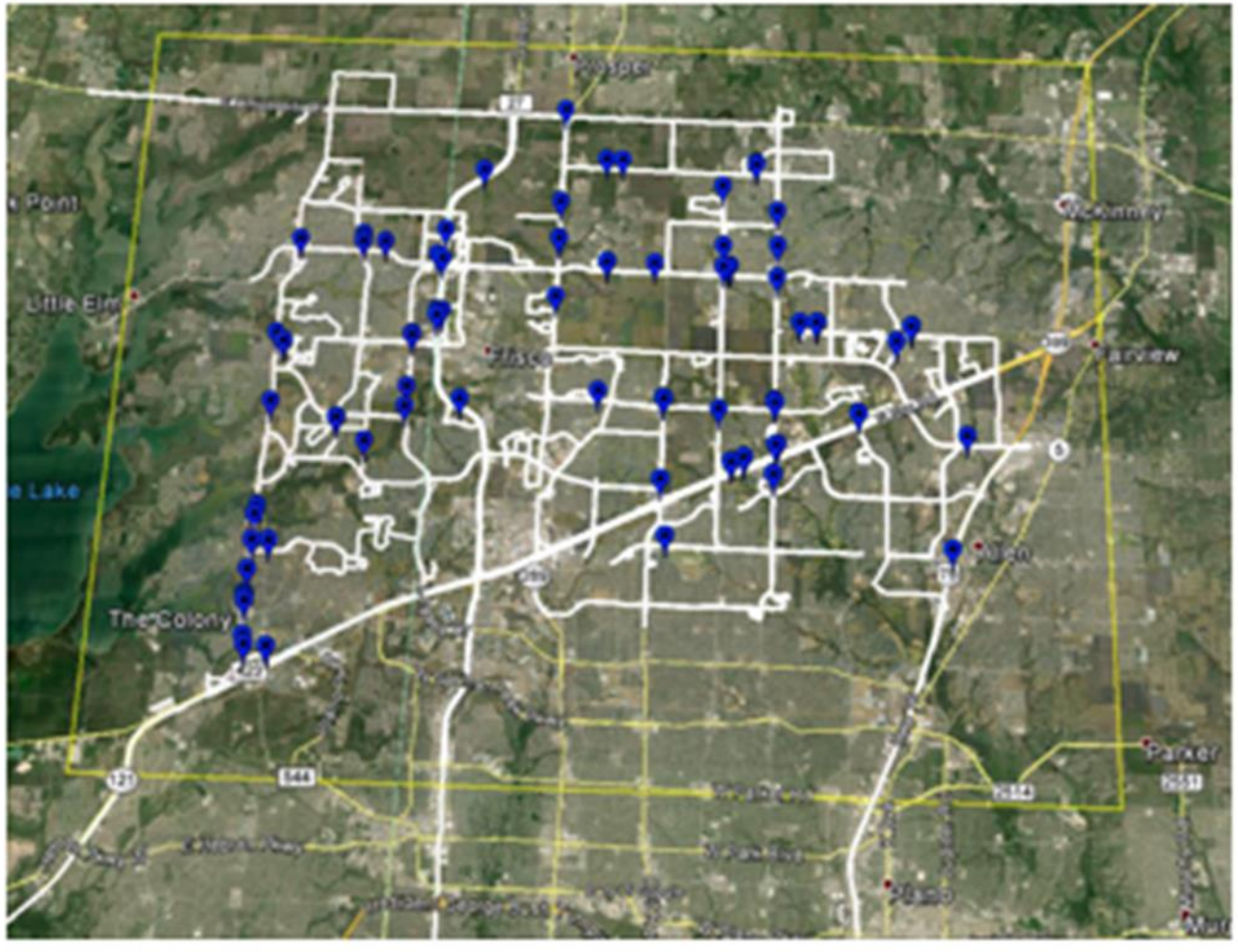
The **1,161** **RED** Failure Signature Events are captured by the EXACTER RF Assessment.



Targeted Field Work using RF, Ultrasonic, IR, and Visual Methods

The **1,161 RED** Failure Signature Events are captured by the EXACTER RF Assessment.

The *Failure Signature Analysis* identified **77 BLUE** Maintenance Groups where problematic conditions (PD/EMI) are present.



Targeted Field Work using RF, Ultrasonic, IR, and Visual Methods

Ultrasonic Field Locating

- Exacter Field Engineer visit identified structure
- Confirm presence of PD/EMI for 5th time
- Pinpoint specific component(s) responsible for problematic condition

Correlate Historical Data with Field Report

Criticality measure identifies the potential customer minutes of interruption (CMI) an identified component would cause if a failure occurs

1) **Use utility provided connectivity data to identify the number of meters served by identified component**
   - Upstream & downstream to next protective device
2) **Use CAIDI or Average Restoration time to estimate duration of outage**
3) **Meters served x CAIDI = Potential CMI**

Prioritize maintenance operations based on potential impact to system

- Risk & Impact
- Probability

Recommendations for an Integrated Reliability Program

2015 Pilot Assessment

- Top two worst performing districts
- 700 Miles of 3-Phase distribution

2016 Improvement

- 22% reduction of equipment related outages across entire system
- 15% reduction in area of pilot year over after repairs were made
- Year over year analysis also identified 24% increase in lightning arrester failures due to their end-of-life cycle allowing PEC to get ahead of the curve

2017

- Target 900 miles of top worst performing feeders across entire system

Case Study & Results of Pilot and Multiyear Program 2015 thru 2017

2016 Exacter Results

- 2,100 Miles Driven with the Exacter Technology
  - Unique Pieces of Equipment Identified
    - 1 Piece of equipment every 5.95 Miles
      - 353 Components identified
  - 114,065 Customers Impacted
- 9,113,793 Minutes of CMI Potential (79.9 CAIDI)
  - 33.80 Minutes of SAIDI Potential
  - Projected SAIDI Reduction **3.38** (10%)

Total Miles	2,100
Total Customers	269,613
Customer Count	114065.00
Average Duration	79.9
CMI	9,113,793.50
SAIDI Minutes	**33.80**
Equip/Mi	**5.95**
Projected SAIDI Reduction (10%)	**3.38**

Case Study & Results of Pilot and Multiyear Program 2015 thru 2017

Exacter Equipment Identified

Exacter	
Bushing	4%
Cutout	9%
Dead End Bells	12%
Lightning Arresters	10%
Pin Insulators	51%
Post Insulator	2%
Expolitor	2%
Lightning Arresters on Transformer	4%

Case Study & Results of Pilot and Multiyear Program 2015 thru 2017

IR Results

- 2,100 Miles Driven with IR
- Unique Pieces of Equipment Identified
  - 1 Piece of equipment every 13.6 Miles
  - Priority 1 : 10
  - Priority 2 : 4
  - Priority 3 : 11
  - Priority 4 : 129

Temperature Range[1] (Temperature rise over reference)	*Priority Code*	*Action Level – Days to Replace*
< 50 ºF	N/A	No action is required
50 ºF to 86 ºF	4	Schedule replacement within 365 days
87 ºF to 122 ºF	3	Schedule replacement within 180 days
123 ºF to 167 ºF	2	Schedule replacement within 90 days
> 167 ºF	1	Schedule immediate replacement within 30 days

Case Study & Results of Pilot and Multiyear Program 2015 thru 2017

IR Equipment Identified

	Percentage of findings per equipment	
Bushing	15 out of 154	10%
Bypass Switch	1 out of 154	.5%
Capacitor Bank	1 out of 154	.5%
Conductor	2 out of 154	1.5%
Connector/Jumper	23 out of 154	15%
Cutout	1 out of 154	.5%
Fuse	7 out of 154	5%
Lightning Arrester	88 out of 154	57%
Post Insulator	1 out of 154	.5%
Pothead	1 out of 154	.5%
Splice	1 out of 154	.5%
Switch	6 out of 154	4%
Transformer	5 out of 154	3%
Other	2 out of 154	1.5%

Case Study & Results of Pilot and Multiyear Program 2015 thru 2017

Year Over Year Improvement

	2015	2016	Improvement
Total System CMI	28,415,452	19,891,959	30%
Total System 3-phase EQ CMI	1,528,417	968,828	44%
LH CP 3 Phase OH EQ CMI	198,595	551,988	Increase 34%
Outage Events Overall	281	205	28%
Single Phase Events	258	180	29%
3-Phase Events	24	23	5%
Arrester	71	93	Increase 24%
Cutout	30	16	47%
Insulator	5	3	40%
Transformer	139	58	61%
Connections	40	14	65%
Jumpers	32	16	50%

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