Electrical Submersible Pumps (ESPs) & World Energy

- **High production rates** - up to **60,000 BPD**
- **60%** of the total **world oil production** \(^{(1)}\)
- **130,000 installations worldwide** \(^{(1)}\)

\(^{(1)}\) Dunham, 2013
ESP Failures

Example of ESP Failed Item Statistics for One Field - After (Xiao, Shepler, Windiarto, Parkinson, & Fox, 2016)

Components of ESP [from (Alhanati, Solanki, & T. A. Zahacy, 2001)]
Models Available

Modelling Types

Physical-based Modeling
- Develop mathematical equations describing system physical behavior

Knowledge-Based Models
- Created by domain expert without mathematical representation
  - Expert Models
    - Rule based models (if, then, else)
  - Fuzzy Logic Models
    - Values of parameters represented by values between (0-1)

Data-Driven Models
- Uses historical data to build and train models using statistical and learning techniques
  - Supervised Learning
    - Label of classes for training data are known
  - Unsupervised Learning
    - Un-labeled training data (clustering required)
  - Reinforcement Learning
    - No training data: real-time learning based on maximizing “Reward Function”
## Data Available

### Dynamic Data:
- **ESP Data**
- Discharge Pressure:
- Suction Pressure:
- Discharge Temperature:
- Motor Temperature:
- Vibration
- Motor Current:
- Leakage Current:
- Speed (Frequency)

### Static Data:
- **Well Completion Data**
- **ESP Pump Design Information**
- **Reservoir Fluid Properties**

### Historical Data:
- **Historical Well Events**
- **Investigation Reports**
- **Failure and Pull Reports**
- **DIFA Reports**

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**Required for One Investigation!**
Principal Component Analysis (PCA)
A multivariate analysis technique that is used for dimensionality reduction

\[ T_{n \times p} = X_{n \times p} W_{p \times p} \]
Principal Component Analysis (PCA)
Multivariate analysis technique that is used for dimensionality reduction

\[ T_{n \times l} = X_{n \times p} W_{p \times l} \]
Principal Component Analysis (PCA) made simple

(A) Data scatter in XYZ (3D) space, lies on plane => possible to resolve into 2D space
(B) using the 1st and 2nd largest orthogonal variance i.e. Component C1 and C2 respectively
(C) owing to linear dependency
(D) C1 and C2 equal => difficult to determine change in C2 as result of C1
(E) Start to see a differentiation between C1 and C2, more opportunity to jump from 2D to 1D space
(F) Noticeable differentiation between C1 and C2 => straightforward jump from 2D to 1D space

Mohannad Abdelaziz
Software Tools Built
First Installation

1st and 2nd PCs explained more than 66% of the data

<table>
<thead>
<tr>
<th>Installation Date</th>
<th>Start-up Date</th>
<th>Failure Date</th>
<th>Root Cause</th>
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</thead>
</table>
Second Installation

1\textsuperscript{st} and 2\textsuperscript{nd} PCs explained more than 79% of the data

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<th>Failure Date</th>
<th>Root Cause</th>
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Fifth Installation

1\textsuperscript{st} and 2\textsuperscript{nd} PCs explained more than 87\% of the data.

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<th>Root Cause</th>
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<tbody>
<tr>
<td>18-Jan-2016</td>
<td>21-Jan-2016</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>
Fifth Installation

Stable Region 2: 60Hz
PC1 & 2 describe 71.6% of data

Stable Region 2 + 3
Normalised for frequency

One central cluster for normal operating condition
Generalized PCA Model for all Installations

- One PCA model - all installations
- Uniform conclusions about “failure modes” that are applicable to all
- Set the stage for generalization across other wells and fields
- Less susceptible to stable region selection
Generalized PCA Model for all Installations

Combined PCA - For all installations

Combined PCA - All stable regions
Summary of Results

- Failure of downhole sensor has major impact on PCA
- Method presented allowed detection of **anomalies**:
  - Motor temperature variations
  - High current reading
- PCA allowed **additional dynamical changes** in ESP systems:
  - Cluster shift two months prior to failure (1\textsuperscript{st} installation)
  - Distinctive clusters (5\textsuperscript{th} installation)
- Generalized Model Construction
Thank You

Questions?