SAND2016-4303C

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Sandia National Laboratories

Performance Monitoring using Pecos

2016 PV System Symposium

Santa Clara, CA, May 10, 2016

Katherine A. Klise

Sandia National Laboratories, Albuquerque, NM

U.S. DEPARTMENT OF ENERGY

National Nuclear Security Administration

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Overview

- Why use Pecos?
  - Collect large amounts of data on multiple systems and locations
  - Run automatic quality control tests on that data
  - Alert system operators when the system has changed
  - Generate reports
  - Collect performance statistics to track long term system health
  - Compare system performance across sites
- Pecos was developed specifically for solar photovoltaic system monitoring, but it can be customized for other applications

TOA5	CR1000	46385	CR1000.Std.24	CPU:ABQ_RTC_MET_2013_03_21.CR1	58869	DataOut
TIMESTAMP	Global_Wm2_Avg	Direct_Wm2_Avg	Diffuse_Wm2_Avg	Pressure_mBar_Avg	WS_ms_Mean	Wdir_Mean
TS						Deg
	Avg	Avg	Avg	Avg	WVc	WVc
3/26/2013 0:00	-1.16195	-0.45458	0	832.121	6.338	135.7
3/26/2013 0:01	-1.14918	-0.5455	0	832.123	5.8	136.4
3/26/2013 0:02	-1.14918	-0.52277	0	832.106	5.988	131.2
3/26/2013 0:03	-1.14918	-0.45458	0	832.0875	6.838	139.6
3/26/2013 0:04	-1.14918	-0.45458	0	832.0799	6.825	136.8
3/26/2013 0:05	-1.14918	-0.45458	0	832.0693	6.775	137
3/26/2013 0:06	-1.14919	-0.40155	0	832.0547	6.825	135.2
3/26/2013 0:07	-1.14919	-0.31063	0	832.0114	6.85	137.4
3/26/2013 0:08	-1.14921	-0.46217	0	832.0062	7.013	136.3
3/26/2013 0:09	-1.14922	-0.45459	0	832.0159	7	135.1
3/26/2013 0:10	-1.14922	-0.45459	0	832.0093	6.063	136.4
3/26/2013 0:11	-1.14921	-0.45459	0	832.0027	6.825	134.6
3/26/2013 0:12	-1.14921	-0.45459	0	831.9932	6.813	135.8
3/26/2013 0:13	-1.14921	-0.36367	0	831.9811	6.65	137.2
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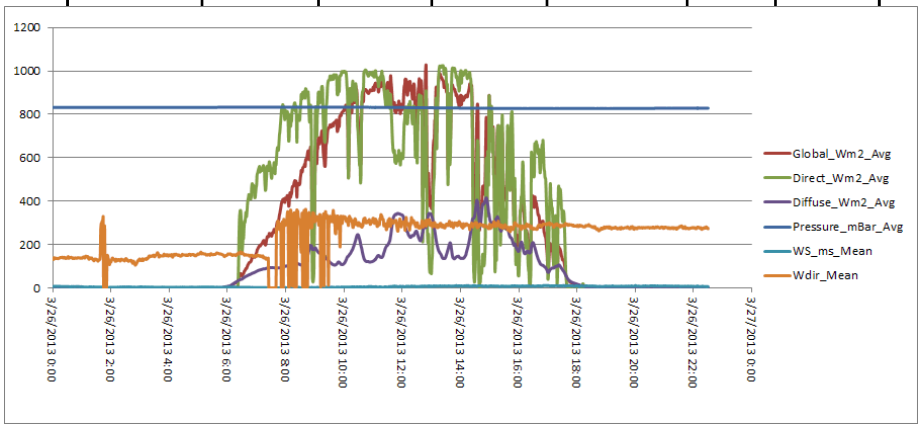
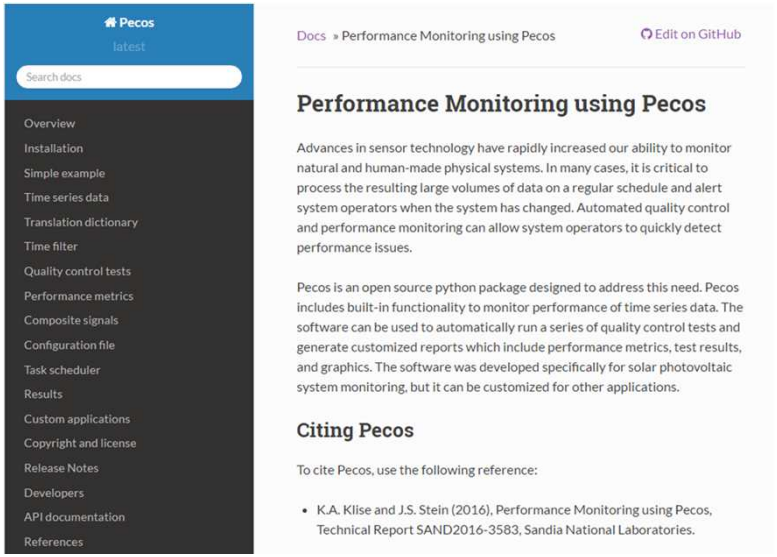
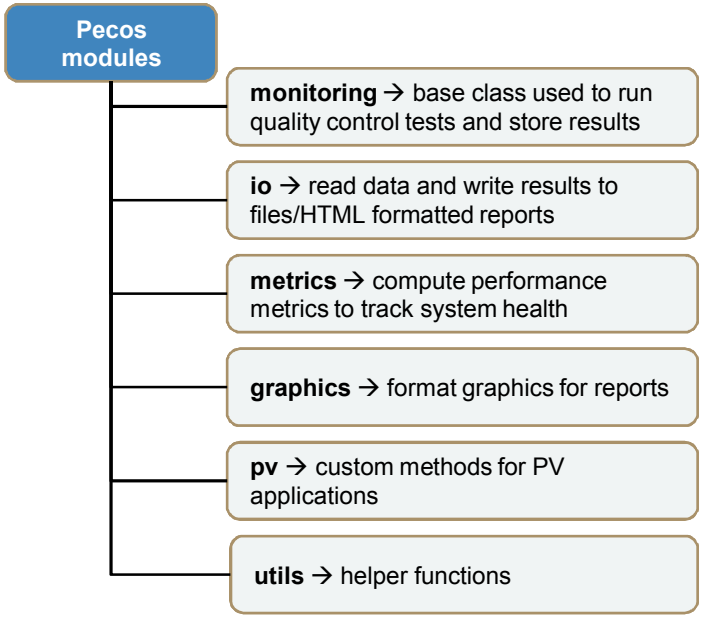
3/26/2013 0:16	-1.1492	-0.45459	0	831.9963	6.613	141.1
3/26/2013 0:17	-1.1492	-0.60612	0	832.0099	6.125	139.8
3/26/2013 0:18	-1.1492	-0.84099	0	832.0046	6.113	139.9



Software Framework

- Open-source python package
  - Revised BSD License
- Software repository
  - https://github.com/sandialabs/pecos
- Documentation
  - http://pecos.readthedocs.org
- Software testing results
  - https://travis-ci.org/sandialabs/pecos
  - https://coveralls.io/github/sandialabs/pecos
- 'Getting started' examples included with the software
  - simple
  - pv
  - metrics
  - dashboard





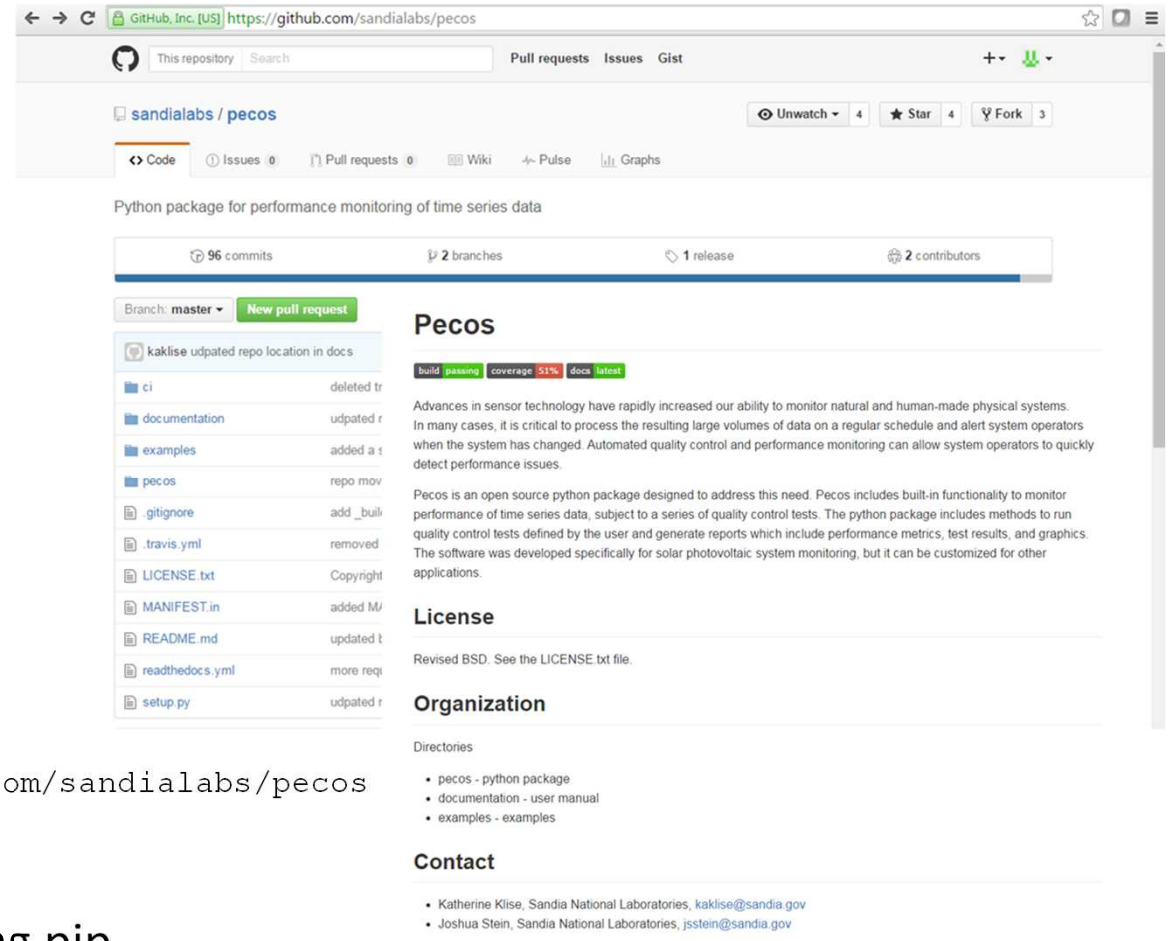
Installation

- Required dependencies
  - Python 2.7
  - pandas
  - numpy
  - matplotlib
- Optional dependencies
  - pvlib
  - pyyaml
  - win32com
  - nose
- Build pecos from source

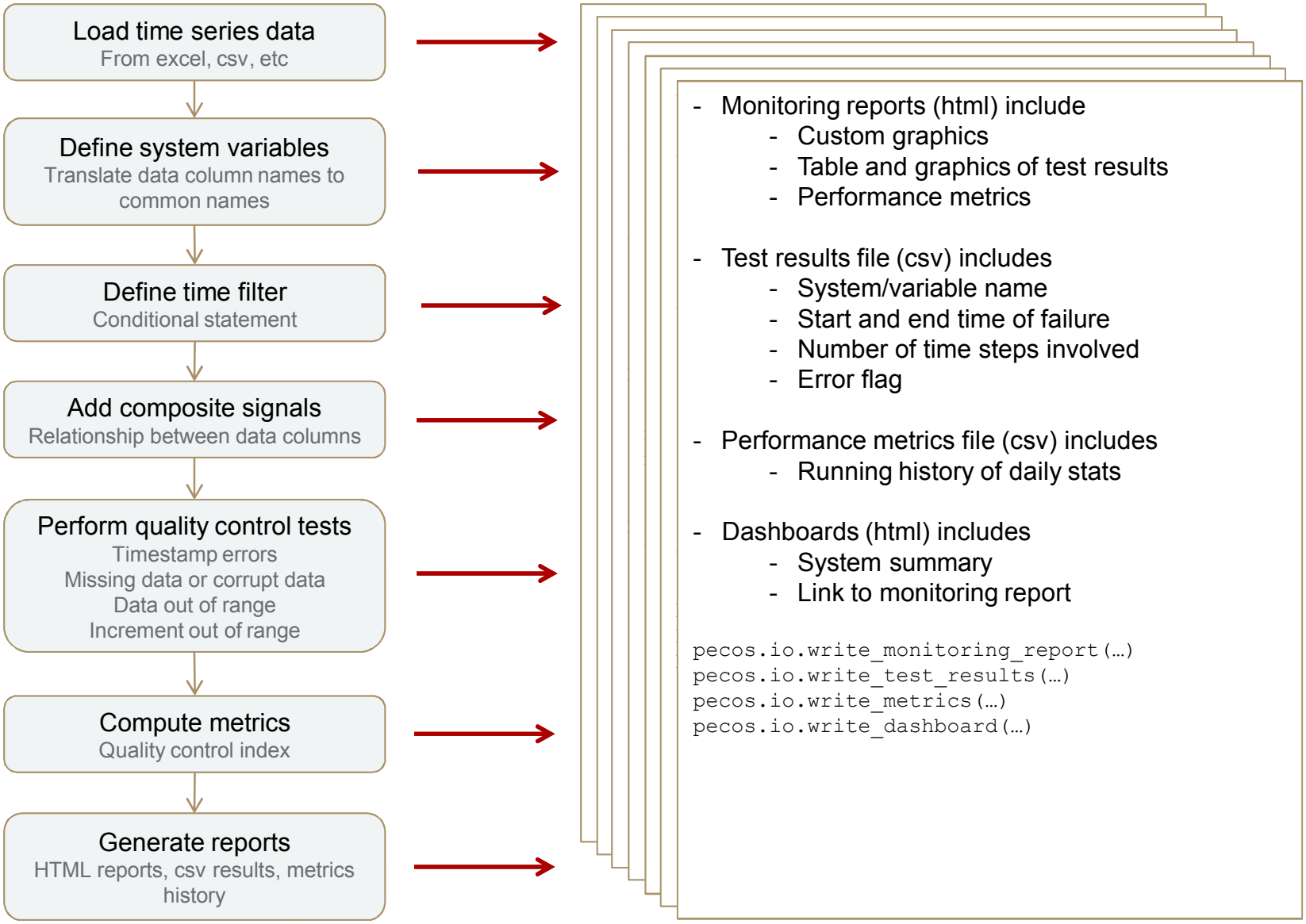
```
git clone https://github.com/sandialabs/pecos
cd pecos
python setup.py install
```

- Install latest release using pip

```
pip install pecos
```

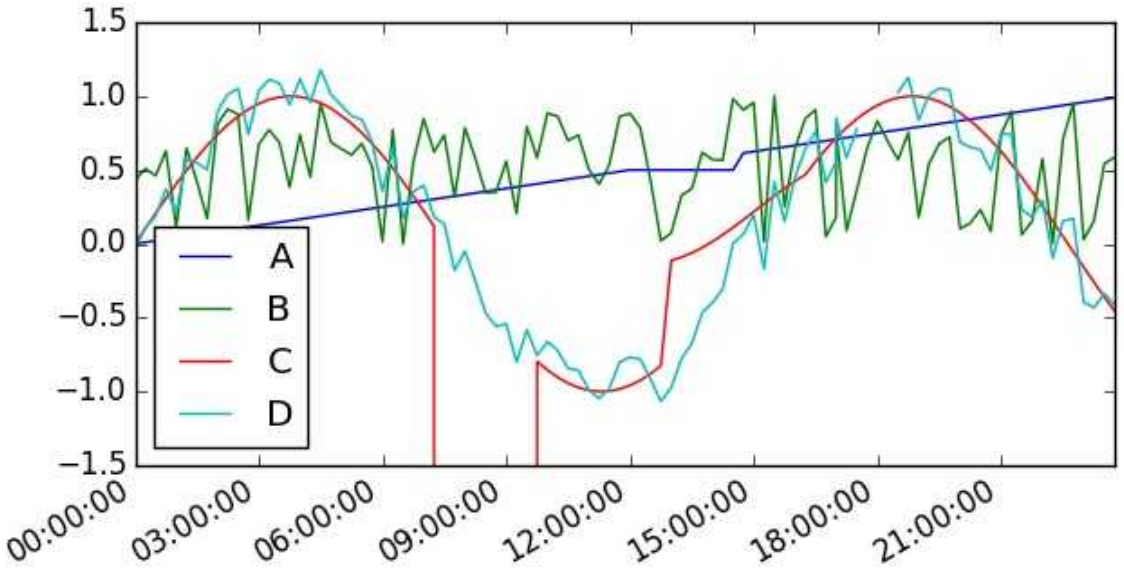


Basic Workflow

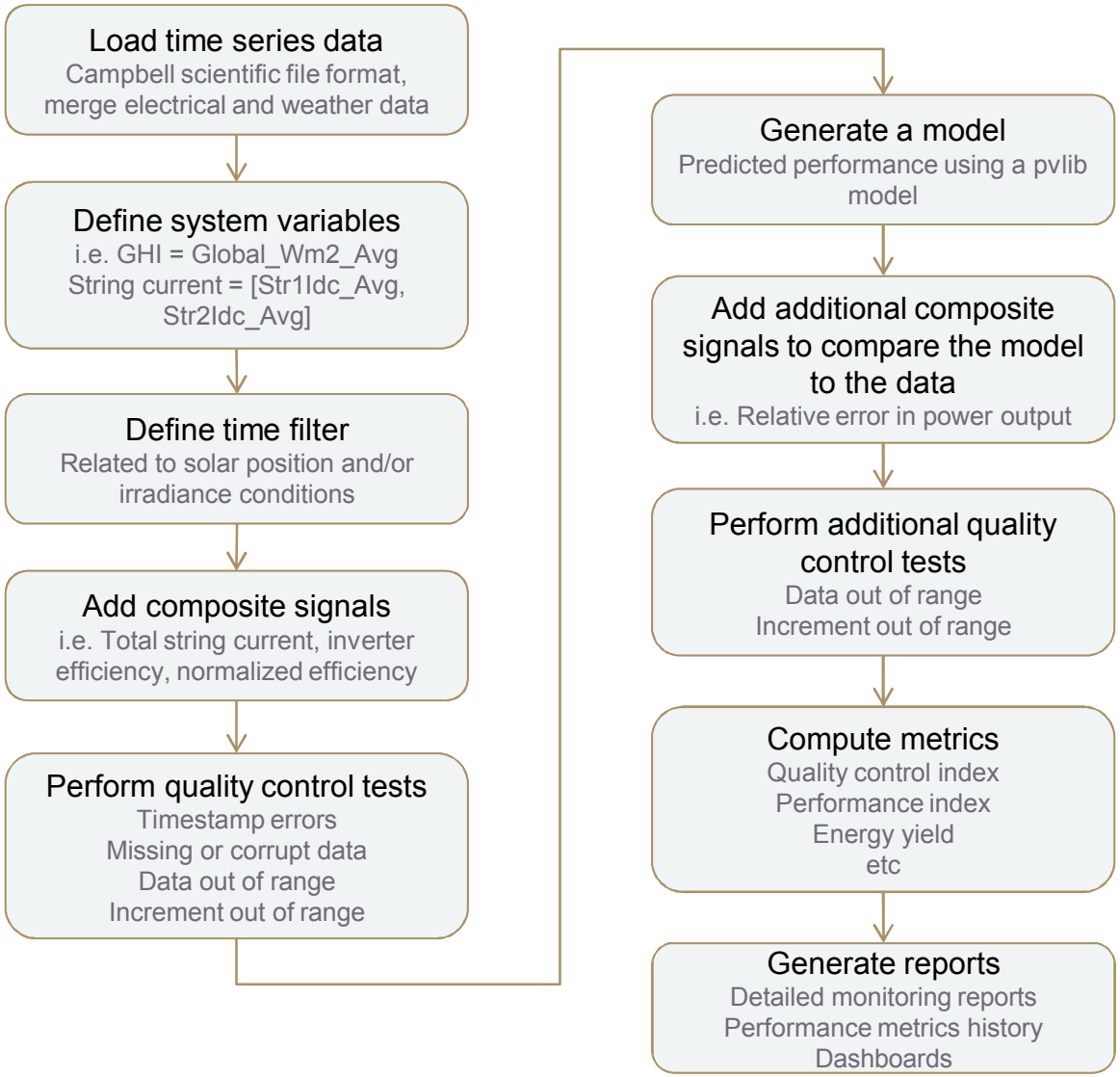


Basic Example

- simple_example.py
  - The data includes missing timestamps, duplicate timestamps, non-monotonic timestamps, corrupt data, data out of expected range, data that doesn't change, and data that changes abruptly.
  - A = elapsed time in days
  - B = uniform random number between 0 and 1
  - C = sin(10*A)
  - D = C+(B-0.5)/2

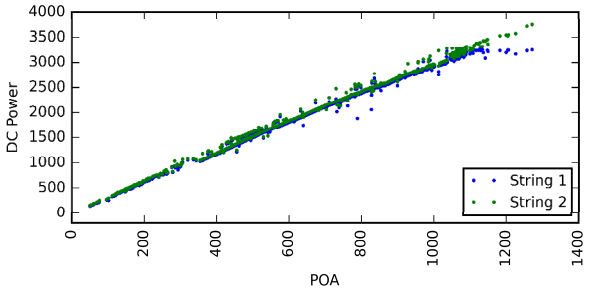


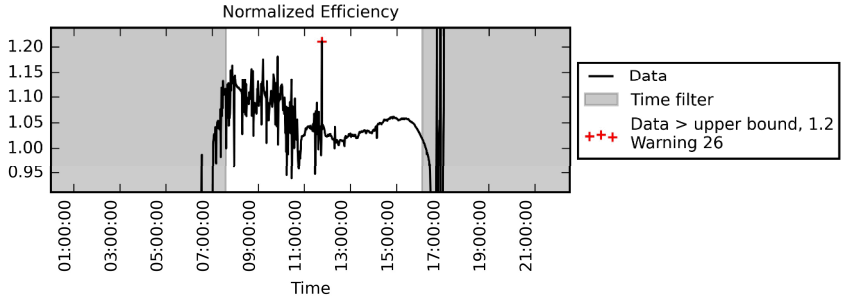
PV Workflow

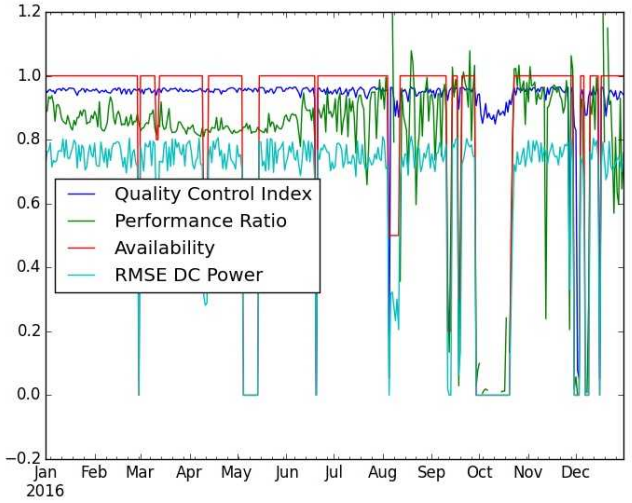

Load time series data
Campbell scientific file format, merge electrical and weather data
Define system variables
i.e. GHI = Global_Wm2_Avg
String current = [Str1Idc_Avg, Str2Idc_Avg]
Define time filter
Related to solar position and/or irradiance conditions
Add composite signals
i.e. Total string current, inverter efficiency, normalized efficiency
Perform quality control tests
Timestamp errors
Missing or corrupt data
Data out of range
Increment out of range
Generate a model
Predicted performance using a pvlib model
Add additional composite signals to compare the model to the data
i.e. Relative error in power output
Perform additional quality control tests
Data out of range
Increment out of range
Compute metrics
Quality control index
Performance index
Energy yield
etc
Generate reports
Detailed monitoring reports
Performance metrics history
Dashboards

PV Examples

- pv_example.py
  - YAML configuration file
  - Electrical and weather data
  - Time filter based on sun position
  - pvlib performance model and metric
- metrics_example.py
  - Track long term system health
  - Performance metrics from daily analysis



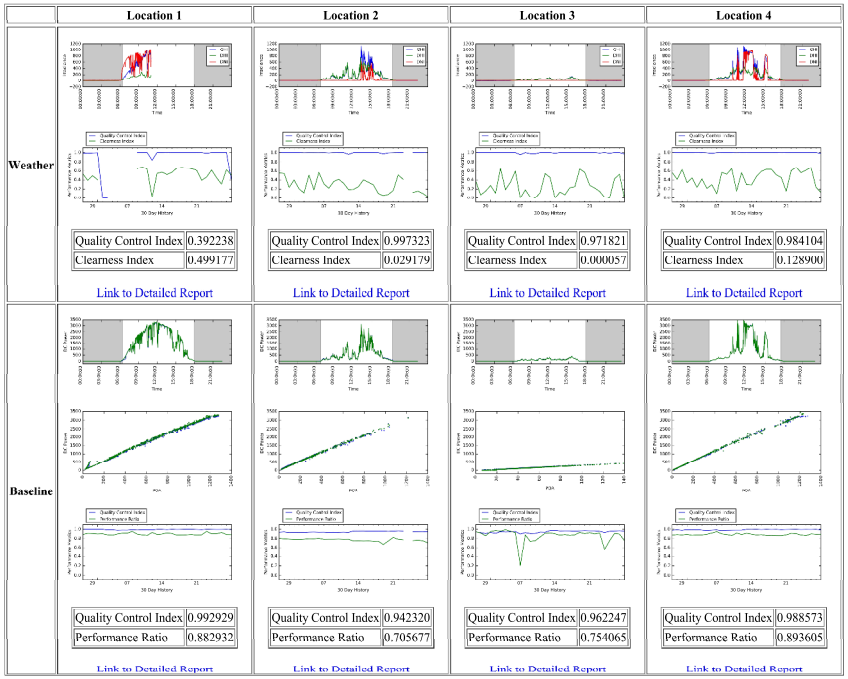




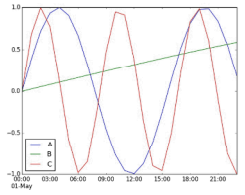
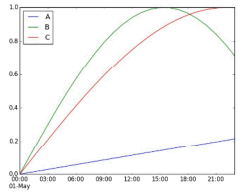
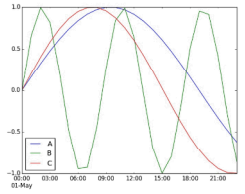
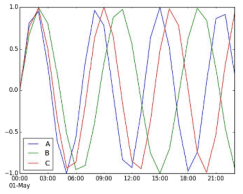
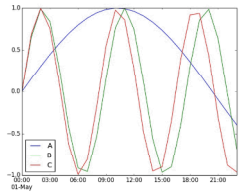
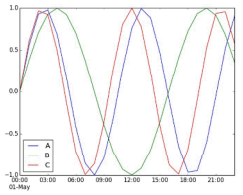
Dashboard Example

- dashboard_example.py →
  - Compare performance of several systems
  - Generic dashboard
  - Includes text, graphics, table and link

Pecos Dashboard for 2016-03-28



Pecos Dashboard

	location1	location2
system1	Example text for location1_system1  Quality Control Index 0.784314 Link to Report	Example text for location2_system1  Quality Control Index 0.72549 Link to Report
system2	Example text for location1_system2  Quality Control Index 0.555556 Link to Report	Example text for location2_system2  Quality Control Index 0.6 Link to Report
system3	Example text for location1_system3  Quality Control Index 0.384615 Link to Report	Example text for location2_system3  Quality Control Index 0.461538 Link to Report

This report was generated by Pecos 0.1.1, 05/02/2016

Future Development

- Integration with IEC 61724
  - Photovoltaic system performance monitoring - Guidelines for measurement, data exchange and analysis
- Four types of filters
  - Range, missing data, dead value , abrupt change
- Example quality control tests
  - Power sensor is out of range if the value < -0.01*rating or > 1.02*rating
  - Irradiance sensor is dead if the derivative < 0.0001 W/m2 while value > 5 W/m2 (15 minute data)
  - Temperature sensor is erratic if the derivative > 4 C (15 minute data)
- Precision requirements (Class A,B,C)
- Data binned into times when inverters were on line and off line
- Account for calibration accuracy
- Integrate performance model, compare expected power with measured power
- Compute metrics (performance ratio, power performance index, …)