Intro Examples — pvlib-python 0.6.1+0.gd621327.dirty documentation

Modeling paradigms

The backbone of pvlib-python is well-tested procedural code that implements PV system models. pvlib-python also provides a collection of classes for users that prefer object-oriented programming. These classes can help users keep track of data in a more organized way, provide some “smart” functions with more flexible inputs, and simplify the modeling process for common situations. The classes do not add any algorithms beyond what’s available in the procedural code, and most of the object methods are simple wrappers around the corresponding procedural code.

Let’s use each of these pvlib modeling paradigms to calculate the yearly energy yield for a given hardware configuration at a handful of sites listed below.

```
In [1]: import pandas as pd

In [2]: import matplotlib.pyplot as plt

In [3]: naive_times = pd.DatetimeIndex(start='2015', end='2016', freq='1h')

# very approximate
# latitude, longitude, name, altitude, timezone
In [4]: coordinates = [(30, -110, 'Tucson', 700, 'Etc/GMT+7'),
   ...:                (35, -105, 'Albuquerque', 1500, 'Etc/GMT+7'),
   ...:                (40, -120, 'San Francisco', 10, 'Etc/GMT+8'),
   ...:                (50, 10, 'Berlin', 34, 'Etc/GMT-1')]
   ...:

In [5]: import pvlib

# get the module and inverter specifications from SAM
In [6]: sandia_modules = pvlib.pvsystem.retrieve_sam('SandiaMod')

In [7]: sapm_inverters = pvlib.pvsystem.retrieve_sam('cecinverter')

In [8]: module = sandia_modules['Canadian_Solar_CS5P_220M___2009_']

In [9]: inverter = sapm_inverters['ABB__MICRO_0_25_I_OUTD_US_208_208V__CEC_2014_']

# specify constant ambient air temp and wind for simplicity
```

```
In [10]: temp_air = 20

In [11]: wind_speed = 0
```

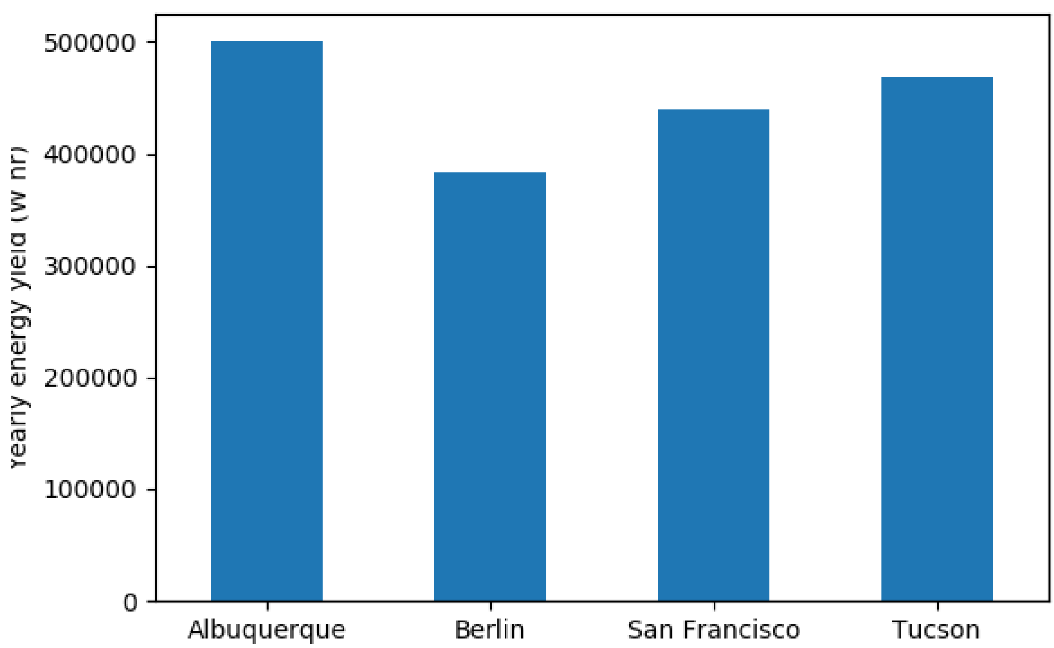
Procedural

The straightforward procedural code can be used for all modeling steps in pvlib-python.

The following code demonstrates how to use the procedural code to accomplish our system modeling goal:

```
In [12]: system = {'module': module, 'inverter': inverter,
   ....:           'surface_azimuth': 180}
   ....:

In [13]: energies = {}

In [14]: for latitude, longitude, name, altitude, timezone in coordinates:
   ....:     times = naive_times.tz_localize(timezone)
   ....:     system['surface_tilt'] = latitude
   ....:     solpos = pvlib.solarposition.get_solarposition(times, latitude, longitude)
   ....:     dni_extra = pvlib.irradiance.get_extra_radiation(times)
   ....:     airmass = pvlib.atmosphere.get_relative_airmass(solpos['apparent_zenith'])
   ....:     pressure = pvlib.atmosphere.alt2pres(altitude)
   ....:     am_abs = pvlib.atmosphere.get_absolute_airmass(airmass, pressure)
   ....:     tl = pvlib.clearsky.lookup_linke_turbidity(times, latitude, longitude)
   ....:     cs = pvlib.clearsky.ineichen(solpos['apparent_zenith'], am_abs, tl,
   ....:                                  dni_extra=dni_extra, altitude=altitude)
   ....:     aoi = pvlib.irradiance.aoi(system['surface_tilt'],
system['surface_azimuth'],
   ....:                                solpos['apparent_zenith'], solpos['azimuth'])
   ....:     total_irrad = pvlib.irradiance.get_total_irradiance(system['surface_tilt'],
   ....:
system['surface_azimuth'],
   ....:
solpos['apparent_zenith'],
   ....:                                                         solpos['azimuth'],
   ....:                                                         cs['dni'], cs['ghi'],
cs['dhi'],
   ....:                                                         dni_extra=dni_extra,
   ....:                                                         model='haydavies')
   ....:     temps = pvlib.pvsystem.sapm_celltemp(total_irrad['poa_global'],
   ....:                                          wind_speed, temp_air)
   ....:     effective_irradiance = pvlib.pvsystem.sapm_effective_irradiance(
   ....:         total_irrad['poa_direct'], total_irrad['poa_diffuse'],
```

```
   ....:         am_abs, aoi, module)
   ....:     dc = pvlib.pvsystem.sapm(effective_irradiance, temps['temp_cell'], module)
   ....:     ac = pvlib.pvsystem.snlinverter(dc['v_mp'], dc['p_mp'], inverter)
   ....:     annual_energy = ac.sum()
   ....:     energies[name] = annual_energy
   ....:

In [15]: energies = pd.Series(energies)

# based on the parameters specified above, these are in W*hrs
In [16]: print(energies.round(0))
Albuquerque      500451.0
Berlin           383547.0
San Francisco    440046.0
Tucson           467740.0
dtype: float64

In [17]: energies.plot(kind='bar', rot=0)
Out[17]: <matplotlib.axes._subplots.AxesSubplot at 0x7f4eddf01518>

In [18]: plt.ylabel('Yearly energy yield (W hr)')
Out[18]: Text(0, 0.5, 'Yearly energy yield (W hr)')
```



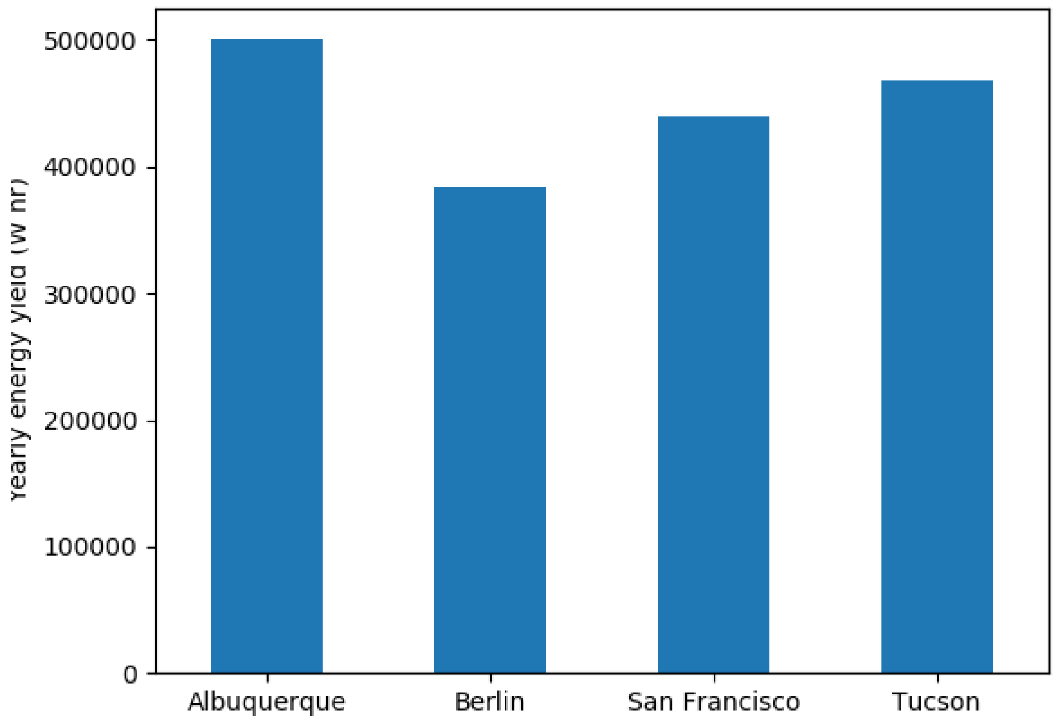
Object oriented (Location, PVSystem, ModelChain)

The first object oriented paradigm uses a model where a `PVSystem` object represents an assembled collection of modules, inverters, etc., a `Location` object represents a particular place on the planet, and a `ModelChain` object describes the modeling chain used to calculate PV output at that Location. This can be a useful paradigm if you prefer to think about the PV system and its location as separate concepts or if you develop your own ModelChain subclasses. It can also be helpful if you make extensive use of Location-specific methods for other calculations. pvlib-python also includes a `SingleAxisTracker` class that is a subclass of `PVSystem`.

The following code demonstrates how to use `Location`, `PVSystem`, and `ModelChain` objects to accomplish our system modeling goal. ModelChain objects provide convenience methods that can provide default selections for models and can also fill necessary input data with modeled data. In our example below, we use convenience methods. For example, no irradiance data is provided as input, so the ModelChain object substitutes irradiance from a clear-sky model via the prepare_inputs method. Also, no irradiance transposition model is specified (keyword argument *transposition* for ModelChain) so the ModelChain defaults to the *haydavies* model. In this example, ModelChain infers the DC power model from the module provided by examining the parameters defined for module.

```
In [19]: from pvlib.pvsystem import PVSystem

In [20]: from pvlib.location import Location

In [21]: from pvlib.modelchain import ModelChain

In [22]: system = PVSystem(module_parameters=module,
   ....:                   inverter_parameters=inverter)
   ....:

In [23]: energies = {}

In [24]: for latitude, longitude, name, altitude, timezone in coordinates:
   ....:     times = naive_times.tz_localize(timezone)
   ....:     location = Location(latitude, longitude, name=name, altitude=altitude,
   ....:                         tz=timezone)
   ....:     mc = ModelChain(system, location,
   ....:                     orientation_strategy='south_at_latitude_tilt')
   ....:     mc.run_model(times)
   ....:     annual_energy = mc.ac.sum()
   ....:     energies[name] = annual_energy
   ....:

In [25]: energies = pd.Series(energies)

# based on the parameters specified above, these are in W*hrs
In [26]: print(energies.round(0))
Albuquerque      500372.0
```

```
Berlin           383544.0
San Francisco    440046.0
Tucson           467704.0
dtype: float64

In [27]: energies.plot(kind='bar', rot=0)
Out[27]: <matplotlib.axes._subplots.AxesSubplot at 0x7f4ee4c36630>

In [28]: plt.ylabel('Yearly energy yield (W hr)')
Out[28]: Text(0, 0.5, 'Yearly energy yield (W hr)')
```



Object oriented (LocalizedPVSystem)

The second object oriented paradigm uses a model where a `LocalizedPVSystem` represents a PV system at a particular place on the planet. This can be a useful paradigm if you're thinking about a power plant that already exists.

The `LocalizedPVSystem` inherits from both `PVSystem` and `Location`, while the `LocalizedSingleAxisTracker` inherits from `SingleAxisTracker` (itself a subclass of `PVSystem`) and `Location`. The `LocalizedPVSystem` and `LocalizedSingleAxisTracker` classes may contain bugs due to the relative difficulty of implementing multiple inheritance. The `LocalizedPVSystem` and `LocalizedSingleAxisTracker` may be deprecated in a future release. We recommend that most modeling workflows implement `Location`, `PVSystem`, and `ModelChain`.

The following code demonstrates how to use a `LocalizedPVSystem` object to accomplish our modeling goal:

```
In [29]: from pvlib.pvsystem import LocalizedPVSystem

In [30]: energies = {}

In [31]: for latitude, longitude, name, altitude, timezone in coordinates:
   ....:     localized_system = LocalizedPVSystem(module_parameters=module,
   ....:                                          inverter_parameters=inverter,
   ....:                                          surface_tilt=latitude,
   ....:                                          surface_azimuth=180,
   ....:                                          latitude=latitude,
   ....:                                          longitude=longitude,
   ....:                                          name=name,
   ....:                                          altitude=altitude,
   ....:                                          tz=timezone)
   ....:     times = naive_times.tz_localize(timezone)
   ....:     clearsky = localized_system.get_clearsky(times)
   ....:     solar_position = localized_system.get_solarposition(times)
   ....:     total_irrad =
localized_system.get_irradiance(solar_position['apparent_zenith'],
   ....:                                                   solar_position['azimuth'],
   ....:                                                   clearsky['dni'],
   ....:                                                   clearsky['ghi'],
   ....:                                                   clearsky['dhi'])
   ....:     temps = localized_system.sapm_celltemp(total_irrad['poa_global'],
   ....:                                            wind_speed, temp_air)
   ....:     aoi = localized_system.get_aoi(solar_position['apparent_zenith'],
   ....:                                    solar_position['azimuth'])
   ....:     airmass = localized_system.get_airmass(solar_position=solar_position)
   ....:     effective_irradiance = localized_system.sapm_effective_irradiance(
   ....:         total_irrad['poa_direct'], total_irrad['poa_diffuse'],
   ....:         airmass['airmass_absolute'], aoi)
   ....:     dc = localized_system.sapm(effective_irradiance, temps['temp_cell'])
   ....:     ac = localized_system.snlinverter(dc['v_mp'], dc['p_mp'])
   ....:     annual_energy = ac.sum()
   ....:     energies[name] = annual_energy
   ....:

In [32]: energies = pd.Series(energies)

# based on the parameters specified above, these are in W*hrs
In [33]: print(energies.round(0))
Albuquerque      500372.0
Berlin           383544.0
San Francisco    440046.0
```

```
Tucson          467704.0
dtype: float64

In [34]: energies.plot(kind='bar', rot=0)
Out[34]: <matplotlib.axes._subplots.AxesSubplot at 0x7f4ee4c892b0>

In [35]: plt.ylabel('Yearly energy yield (W hr)')
Out[35]: Text(0, 0.5, 'Yearly energy yield (W hr)')
```