SRCL/Gantner Instruments Naming Convention Status
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Introduction

SRCL has written naming conventions for several companies including Gantner Instruments which have been used for many years.

SRCL wrote on 2nd-Mar-2020 [1] regarding adding the MPM and LFM to PVLIB and mentioned the need to add extra functionality to the naming convention but was unaware then of this work [2][3].

For the PV services at Gantner Instruments we developed the naming convention and structure on a wide variety of sites including Outdoor Test Facilities, Central and decentral PV Power plants fig 1 [4].

Fig 1 : Overview of Gantner instruments' naming convention presented 8th PVPMC 2017

As work progressed the naming convention had to be tightened up so that there was one unique name for each variable, which could be validated automatically and coding could be automated.

We have noted down our expertise and recommendations form parsing multiple thousands of channels for different types of customers and assets worldwide.

Summary

Some of the techniques on the PVPMC site would work for small scale sample code but may cause problems on large systems due to inconsistent variable names, also would be harder to parse and validate

We need to come up with some standard for variable names, modifiers, levels, id and separators.

Specific comments

1) There are inconsistencies in abbreviations and full names (e.g. I and current, inv and inverter)

2) Also there inconsistencies in name order e.g.

- airmass_relative and relative_humidity
- pmp vs. max_inv_ac_power
- Apparent_solar_zenith and energy_apparent

3) Some names seem too long for general use (do we really need to spell out temperature and resistance each time?) This may be ok for sample routines but cannot be used in some large systems that have limits on lengths of variable names (e.g. we have a 24 character limit for some systems for variable+modifiers+level+id).

4) Some missing names need to be added e.g. nmot, rsc, roc, ptc, lic (this will be ongoing but need to be checked for duplication and conformance).

5) The suffixes need to be split further as there are 3 different types for "level", "measurement type" and "aggregation" that may all be used together or in different combinations

6) Try to maintain "similarity of variable names" for example with irradiance types on a plane such as ghi and dni, use "p" (or something similar like t) for poa to be similar to horizontal and normal as in table I

Table I : Irradiance 3 letter acronyms (can be extended)

1 type	2 plane	3 irradiance
g=global	h=horizontal	i=irradiance
d=direct or beam	n=normal to sun	
f=diffuse	p=poa (or t)	Could use
r=reflected		h = insolation
s=sky		
x=extraterrestrial		

7) If we can use isc for dc, why not vac for ac?

8) CamelCase variable names without separators have been used previously and work well so that these are distinct from Levels and ID such as AirMass or SolarZenith.

I don't see why we should use python conventions if it doesn't fit well with present usage

9) We can't parse automatically the name meaning (variable name, modifier, level and id) if we allow the same "_" in variable names and between the range name parts such as suffixes and id. We either need different separators or CamelCaseVariables

10) Single letter abbreviations for variables can make coding much easier e.g.

- D = Direct or Beam Irradiance
- F = diFfuse Irradiance
- E = Energy
- G = Global Irradiance
- H = Insolation
- I = Current
- M = Mass
- P = Power
- Q = Reactive power (VAr)
- R = Resistance
- S = Complex power (VA)
- T = Temperature
- V = Voltage

10) Corrections for temperature, angle of incidence etc. need to be allowed e.g. to differentiate Isc uncorrected vs. temperature corrected (e,g, Tmod and alphaISC) see ref [3] *"uncorrected or temperature corrected" (e.g. "nIsc_T") so need an idea if this is OK to use as the naming convention document just allows names like i_sc and v_oc.*

11)There may be a better take up of this if there's automatic name translation possible from the users' conventions to this work, maybe even a short form and a long form e.g. Rs and resistance_series. This will only be possible with unique and well defined variable names. This also ensures that everything the users already use must be covered here

12) A flow chart or other diagram would be useful to ensure names are unique and consistent. For example all the possible words in the first part of the variable name, all the modifiers and it which order, all the levels and then representative IDs.

References

[1] https://github.com/pvlib/pvlib-python/issues/925

[2] https://duramat.github.io/pv-terms/

[3] https://pvpmc.sandia.gov/standardize-pv-modeling-variable-names/

[4] "Optimized PV performance using state of the art monitoring for increased asset value Juergen Sutterlueti et al. 8th PVPMC Albuquerque; 2017" slide 8
https://www.slideshare.net/sandiaecis/21-gi-8thpvpmctalkabqfinalext170508t19new

PV Modeling Glossary

This page contains nomenclature for PV-relevant terms that are used in modeling and data analysis for PV systems. Terms are grouped by category.

The pv-terms project is a work in progress. The team would greatly appreciate feedback and suggestions. To comment, see the issues on the pv-terms github repo.

Version: 0.1.0

Abbreviations

These abbreviations are used without expansion in the rest of the variables.

- **ac**: alternating current
- **aod**: aerosol optical depth
- **aoi**: angle of incidence
- **coeff**: coefficient
- **dc**: direct current
- **dhi**: direct horizontal irradiance
- **dni**: direct normal irradiance
- **ghi**: global horizontal irradiance
- **gpi**: (or equivalent for p=plane of array FOR SIMPLICITY)
- **imp**: current at maximum power
- **inv**: inverter (later "inverter" is used)
- **isc**: current at short circuit
- **max**: maximum
- **min**: minimum
- **mp**: maximum power
- **mpp**: maximum power point
- **mppt**: maximum power point tracking
- **noct**: nominal operating cell temperature
- **nmot: nominal module operating temperature**
- **num**: number (use "qty" for quantity? for clarity as some coders use num to refer to a specific component number)
- **oc**: open circuit
- **pmp**: power at maximum power

- **poa**: plane of array (irradiance) (can shortened to "p" in "gpi")
- **ref**: reference
- **sc**: short circuit
- **stc**: standard test conditions (also include ptc, lic, ltc, htc …)
- **vmp**: voltage at maximum power
- **voc**: voltage at open circuit

Optional Suffixes

These optional suffixes can be appended to a variable in order to further clarify which quantity the variable refers to. In the following * refers to another variable.

Need to separate into 3 DIFFERENT types of suffixes and come up with a naming order e.g. voc_string_rated not voc_rated_string

1) "LEVEL" (first suffix)

- ***_cell**: Quantity relating to a single PV cell
- ***_module**: Quantity relating to a single PV module
- ***_string**: Quantity relating to a string of PV modules.
- ***_array**: Quantity relating to a number of PV strings.
- ***_inv**: Quantity relating to an inverter. (why is it already abbreviated?)
- Combiner box?
- Station?
- SubStation?
- Site?
- Other?

2) "MEASUREMENT TYPE" (second suffix)

- ***_rated**: Parameter on the datasheet or as-built. (or use ref?)
- ***_sim**: Parameter predicted from a model, e.g. voc_sim
- ***_meas**: Parameter measured from field data, e.g. voc_meas
- ***_norm**: normalised by STC values as used in LFM
- ***_diff** : = meas – sim (or resid if this is confusing with diffuse)

3) AGGREGATION (third suffix – need aggregation type and time scale)

- ***_interval**: Quantity integrated over a specific length of time, usually a shorter timespan e.g. day or hour. Is there a code for the interval e.g. "5min", "1h"
- ***_cumulative**: Quantity integrated over a specific length of time, usually the full lifetime of the system. → cum
- ***_sum**
- ***_avg, max, min etc.**

Location

These variables are associated with the location of the PV system.

- **tz**: timezone
- **latitude** [degrees]: Latitude between -90 and 90 degrees. Positive north of the equator.
- **longitude** [degrees]: Longitude between -180 to 180 degrees. Positive east of the meridian.
- **elevation** [m]: Elevation of system above sea level.
- **pressure** [Pa]: Atmospheric pressure at ground level.
- **albedo** [dimensionless]: Ground reflectance between 0 and 1.

Atmosphere

Atmosphere variables are related to weather conditions.

Try to use the same word in the same place e.g. "airmass_relative" but "relative_humidity" which is confusing

- **airmass** [dimensionless]: airmass
- **airmass_relative** [dimensionless]: relative airmass
- **airmass_absolute** [dimensionless]: absolute airmass
- **dew_point** [C]: Dewpoint temperature.
- **relative_humidity** [dimensionless]: The ratio of the partial pressure of water vapor to the equilibrium vapor pressure of water at a given temperature, unitless.
- **specific_humidity** [dimensionless]: The ratio of the mass of water vapor to the total mass of moist air.
- **absolute_humidity** [kg/m^3]: Mass of water vapor per volume of air.
- **total_precipitable_water** [mm]: Depth of water in a column of the atmosphere, if all the water in that column were precipitated as rain. → tpw
- **wind_speed** [m/s]: Wind speed measured at standard 10 meter height.

- **wind_direction** [degrees]: Direction of origin of wind. The wind azimuth convention is defined as degrees east of north (e.g. North=0, South=180, East=90, West=270).

Solar Position

These variables are related to the position of sun and the incidence angles with the PV array.

"Apparent" should come after the measurement as in power_apparent?

- **apparent_solar_elevation** [degrees]: Refraction-corrected solar elevation angle.
- **apparent_solar_zenith** [degrees]: Refraction-corrected solar zenith angle.
- **solar_azimuth** [degrees]: Azimuth angle of the sun in degrees East of North
- **solar_elevation** [degrees]: Elevation angle of the sun.
- **solar_zenith** [degrees]: Zenith angle of the sun.

DC Output

These variables are related to the DC side of a PV power plant.

- **vmp** [V]: Voltage at the maximum power point. [Deprecated/alternates: *v_mp*]
- **imp** [A]: Current at the maximum power point. [Deprecated/alternates: *i_mp*]
- **pmp** [W]: Power at the maximum power point. [Deprecated/alternates: *p_mp*]
- **voc** [V]: Open circuit voltage. [Deprecated/alternates: *v_oc, voltage_oc*]
- **isc** [A]: Short circuit current. [Deprecated/alternates: *i_sc*]
- **roc** [Ohms]: Resistance = -1/(dI/dV) at V = voc, I=0 as in LFM
- **rsc** [Ohms]: Resistance = -1/(dI/dV) at V = 0, I=Isc as in LFM
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- **power_dc** [W]: DC power. → pdc

AC Output

These variables are related to the AC side of a PV power plant.

Why not iac as we can use idc or imp. Similarly use e for energy, p for power pac, v for voltage vac, f for frequency

- **current_ac** [A]: Root-mean-squared AC current on a single phase inverter. → iac

- **current_ac_a** [A]: Root-mean-squared AC current on phase a of a three phase inverter. Use _b or _c for the other phases. → Iac_a
- **energy_apparent** [kWh]: Integral of apparent power over time. → E_app
- **energy_reactive** [kWh]: Integral of reactive power over time. → E_react or Q
- **energy_real** [kWh]: Integral of real power over time. → E_real or S
- **frequency** [Hz]: AC frequency.
- **frequency_a** [Hz]: AC frequency on phase a. Use _b, _c for other phases.
- **power_ac** [W]: Cycle-averaged AC power on a single phase inverter. → Pac
- **power_ac** [W]: Root-mean-squared AC power same as previous
- **power_ac_a** [W]: Cycle-averaged AC power on phase a of a three phase inverter. Use _b or _c for the other phases. → Pac_a
- **power_apparent** [VA]: Cycle-averaged AC apparent power. → Pac_app
- **power_factor** [dimensionless]: Power factor. → Pfactor
- **power_factor_a** [dimensionless]: Power factor on phase a of a three phase inverter. Use _b or _c for the other phases.
- **power_reactive** [VAR]: Cycle-averaged reactive power.
- **power_real** [W]: Cycle-averaged AC power.
- **power_real_a** [W]: Cycle-averaged AC power on phase a.
- **voltage_ac** [V]: Root-mean-squared AC voltage on a single phase inverter. → Vac
- **voltage_ac_a** [V]: Root-mean-squared AC voltage on phase a of a three phase inverter. Use _b or _c for the other phases. → Vac_a

Inverter

These parameters are related to the operation of inverters.

Here you use max before the parameter, surely it's more logical to do iac_max_inv, vmppt_min

- **max_inv_ac_current** [A]: Maximum inverter AC output current. → Iac_max_inv
- **max_inv_ac_power** [W]: Maximum inverter AC output power. → Pac_max_inv
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- **max_inv_ac_voltage** [V]: Maximum inverter AC output voltage.
- **max_inv_dc_current** [A]: Maximum inverter DC input current.
- **max_inv_dc_voltage** [V]: Maximum inverter dc input voltage.
- **max_total_harmonic_distortion** [dimensionless]: Maximum total harmonic distortion of inverter AC output.

- **min_inv_ac_voltage** [V]: Minimum inverter AC ouptut voltage, in volts → vac_min_inv

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- **min_inv_start_voltage** [V]: Minimum inverter input DC voltage to start operation, also called the inverter start voltage.
- **min_mppt_voltage** [V]: Minimum array voltage for inverter to engage maximum power point tracking. Should we have an inv? → vmppt_min_inv

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- **max_mppt_voltage** [V]: Maximum array voltage for inverter to engage maximum power point tracking.
- **nominal_inv_ac_voltage** [V]: Nominal inverter AC output voltage.
- **num_mppt_circuits** [dimensionless]: Number of MPPT circuits.
- **min_inv_operating_temperature** [C]: Minimum inverter operating temperature.
- **max_inv_operating_temperature** [C]: Maximum inverter operating temperature.

Irradiance

These variables denote irradiance in units of W/m^2.

Isn't it easier to use kW/m^2?
Suggest unique letters for irradiance variables e.g.
d=direct, g=global, x=extraterrestrial, r=reflected, s=sky
f=diffuse h=horiz, p=poa, n=normal

- **dhi** [W/m^2]: Diffuse horizontal irradiance. Confusing d = diffuse → fhi
- **dni** [W/m^2]: Direct normal irradiance. Confusing d = direct → dni
- **dni_extra** [W/m^2]: Direct normal irradiance at top of atmosphere (extraterrestrial). → xni
- **effective_irradiance** [W/m^2]: Irradiance reaching the module's cells, i.e., in the plane of array, reduced by soiling and reflections, adjusted for spectrum. → gpi_effective
- **ghi** [W/m^2]: Global horizontal irradiance. → ghi
- **poa_diffuse** [W/m^2]: Total diffuse irradiation in plane. sum of ground and sky diffuse. → fpi
- **poa_direct** [W/m^2]: Direct/beam irradiation in plane. → dpi
- **poa_global** [W/m^2]: Global irradiation in plane. sum of diffuse and beam projection. → gpi
- **poa_ground_diffuse** [W/m^2]: In plane ground reflected irradiation → rpi

- **poa_sky_diffuse** [W/m^2]: Diffuse irradiation in plane from scattered light in the atmosphere (without ground reflected irradiation) → spi

PV System

These variables are related to the operating current, voltage and power of PV cells, modules or arrays.

Surely t can represent temperature, or at most tmp ?

- **temperature_cell** [C]: Temperature of the cell. → tcel
- **temperature_module** [C]: temperature of the module. → tmod
- **temperature_air** [C]: ambient dry bulb temperature. → tair
- **efficiency_inverter** [dimensionless]: Inverter efficiency. Real AC power out divided by DC power in. why is inverter written in full and not inv → eff_inv
- **efficiency_inverter_eu** [dimensionless]: Nominal inverter efficiency using European standard.
- **efficiency_inverter_cec** [dimensionless]: Nominal inverter efficiency using CEC standard.
- **spectral_mismatch** [dimensionless]: The ratio of power produced by a PV cell with a particular spectral distribution of light divided by the power produced by a reference spectrum.
- **modules_per_string** [dimensionless]: Number of modules in series in each string.
- **parallel_strings** [dimensionless]: Number of parallel strings in an array of modules.
- **tracker_type**: Tracker type, can be 'fixed', 'single-axis' or 'two-axis'.
- **ground_coverage_ratio** [dimensionless]: A value denoting the ground coverage ratio of a tracker system which utilizes backtracking; i.e. the ratio between the PV array surface area to total ground area. A tracker system with modules 2 meters wide, centered on the tracking axis, with 6 meters between the tracking axes has a gcr of 2/6=0.333. If gcr is not provided, a gcr of 2/7 is default. gcr must be <=1. → gcr standard abbreviation
- **aoi** [degrees]: Angle between direct beam component and surface normal, between 0 and 90.
- **surface_azimuth** [degrees]: Surface azimuth angles. The azimuth convention is defined as degrees east of north (e.g. North=0, South=180, East=90, West=270) → azi_surf

- **surface_tilt** [degrees]: Surface tilt angle. The tilt angle is defined as degrees from horizontal (e.g. surface facing up = 0, surface facing horizon = 90) → til_surf
- **array_height** [m]: Height above ground of the bottom edge of the module for a fixed tilt system.
- **axis_height** [m]: Height above ground of the axis of rotation for a single axis tracker.
- **axis_azimuth** [degrees]: Azimuth of axis of rotation for a single-axis tracking system (e.g. North=0, South=180, East=90, West=270).
- **axis_tilt** [degrees]: Orientation of axis of rotation for a single-axis tracking system relative to horizontal. 0 = horizontal.

Module Parameters

Module parameters are primarily used to describe the electrical characteristic of a PV module.

Prefererable temperature coefficients as 1/C standard (normalised), then to define the module coeff later
e.g. "gamma_pmp_ref ~ -0.0045 1/C" and "gamma_pmp_ref_mod ~ 0.1 W/C"
Why not aIsc, bVoc, gPmp?

- **pmp_ref** [W]: Power at maximum power point at reference conditions.
- **vmp_ref** [V]: Voltage at maximum power point at reference conditions.
- **isc_ref** [A]: Short circuit current at reference conditions.
- **voc_ref** [V]: Open circuit voltage at reference conditions.
- **imp_ref** [A]: Current at maximum power point at reference conditions.
- **alpha_isc** [A/C]: The temperature coefficient of short-circuit current. [Deprecated/alternates: *alpha_sc*]
- **alpha_isc_ref** [A/C]: The temperature coefficient of short-circuit current at reference conditions.
- **alpha_isc_normalized** [1/C]: alpha_isc/isc_ref. The temperature coefficient of short-circuit current divided by the short-circuit current at reference conditions.
- **alpha_isc_ref_normalized** [1/C]: alpha_isc_ref/isc_ref. The temperature coefficient of short-circuit current at reference conditions divided by the short-circuit current at reference conditions.
- **beta_voc** [V/C]: Temperature coefficient of open-circuit voltage.
- **beta_voc_ref** [V/C]: Temperature coefficient of open-circuit voltage at reference conditions.

- **beta_voc_normalized** [1/C]: beta_voc/voc_ref. Temperature coefficient of open-circuit voltage divided by the open-circuit voltage at reference conditions.
- **beta_voc_ref_normalized** [1/C]: beta_voc_ref/voc_ref. Temperature coefficient of open-circuit voltage at reference conditions divided by the open-circuit voltage at reference conditions.
- **gamma_pmp** [W/C]: Temperature coefficient of power at maximum power point. [Deprecated/alternates: *gamma_pdc*]
- **gamma_pmp_ref** [W/C]: Temperature coefficient of power at maximum power point and reference conditions.
- **beta_vmp** [V/C]: Temperature coefficient of voltage at maximum power point.
- **beta_vmp_ref** [V/C]: Temperature coefficient of voltage at maximum power point and reference conditions.
- **alpha_imp** [A/C]: Temperature coefficient of current at maximum power point.
- **alpha_imp_ref** [A/C]: Temperature coefficient of current at maximum power point and reference conditions.
- These next names are too long
- **photocurrent** [A]: Photo-generated current. → Iph ?
- **photocurrent_ref** [A]: Photocurrent at reference conditions. [Deprecated/alternates: *I_L_ref*]
- **saturation_current** [A]: The dark or diode reverse saturation current. → Isat ?
- **saturation_current_ref** [A]: The dark or diode reverse saturation current at reference conditions. [Deprecated/alternates: *I_o_ref*]
- **resistance_series** [Ohm]: Series resistance. → rseries
- **resistance_series_ref** [Ohm]: Series resistance at reference conditions. [Deprecated/alternates: *R_s*] → rseries_ref
- **resistance_shunt** [Ohm]: Shunt resistance. → rshunt
- **resistance_shunt_ref** [Ohm]: Shunt resistance at reference conditions.
- **voltage_thermal** [V]: Thermal voltage per cell, equal to k_B*T/q where k_B is the boltzman constant (in J/K), T is the temperature (in Kelvin) and q is the electron charge (in Coulombs). → this is used as vth
- **nNsVth_ref** [V]: The product of the usual diode ideality factor (n, unitless), number of cells in series (Ns), and cell thermal voltage at reference conditions. This parameter has abbreviations for Ns and Vth in it – can't we define this as a diode factor "a" as has been done in several papers ?
- **nNsVth** [V]: The product of the usual diode ideality factor (n, unitless), number of cells in series (Ns), and cell thermal voltage.
- **cells_in_series** [dimensionless]: Number of cells in series in a PV module. → this is used as ns

- **diode_factor** [dimensionless]: Diode ideality factor. → this is used as n
- **module_area** [m^2]: Module aperture area. The area inside the frame for a rectangular module.
- **module_area_active** [m^2]: Total area of cells in a module.
- **module_area_external** [m^2]: External dimensions of a module.
- **noct** [C]: Nominal operating cell temperature.
- **Nmot (C):** Nominal module operating temperature ← add
- **band_gap_ref** [eV]: Energy bandgap at reference temperature. 1.121 eV for crystalline silicon. EgRef must be >0. For parameters from the SAM CEC module database, EgRef=1.121 is implicit for all cell types in the parameter estimation algorithm used by NREL.
- **irradiance_ref** [W/m^2]: Reference irradiance. Typical value is 1000 W/m^2. → gref
- **temperature_ref** [C]: Reference temperature. Typical value is 25 C. →tref
- **band_gap_temperature_coeff** [1/K]: The temperature dependence of the energy bandgap at reference conditions in units of 1/K. [Deprecated/alternates: *dEgdT*]

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About pv-terms

The pv-terms project standardizes the nomenclature used for photovoltaic (PV) system modeling. A uniform standard for the PV modeling community enables compatibility within and between software packages and data sources.

The nomenclature was designed with the following criteria:

- Emphasize clarity. E.g. temperature_cell is better than temp_cell. → some systems have limited lengths of variable names
- Write out most variables rather than use abbreviations. E.g. use num_cells_in_series rather than N_s. → again, limited lengths also difficult to parse and possibility of confusion with e,g, num_series_cells or similar. Also ns is used in some of the variables
- Style: No spaces or special characters, but underscores are okay. Most variables are completely lower case and separated by underscores → would be good to have different separators within variable names and between suffixes etc.
- Use common PV abbreviations, e.g. ac, dc, poa, mp, etc. → use more
- Organize some variables "taxonomy style" (e.g temperature_cell) and others "human-readable style" (e.g. solar_zenith). It is not necessary to conform all variables to a single style → this makes parsing and consistency much harder
- Variables have a defined unit. e.g. W/m^2 for irradiance.

Contributing

The pv-terms project is a work in progress. The team would greatly appreciate feedback and suggestions. To comment, see the issues on the pv-terms github repo.

User Guide

Modifying Variables

Many variables can be directly used without modification. However, there are many cases where the standard set of variables does not cover a particular application. For this reason, we have provided a list of optional suffixes that can be appended to a variable name.

For example, one application might be to compare simulated and measured maximum-power-point power. In this case, the base variable **pmp** can be modified into **pmp_sim** and **pmp_meas**.

In order to standardize some common naming modifications, we have chosen a common order.

1. **_XX**, where XX is the name of the particular system.
2. **_cell**, **_module**, **_string**, **_array**, **_inv**.
3. **_rated**, **_sim**, **_meas**
4. **_interval**, **_cumulative**

Some examples:

- **temperature_module_12** Module temperature sensor 12.
- **current_dc_inv_2132**: dc-side current from inverter 2132. → idc
- **temperature_module_meas**, **temperature_module_sim**: measured and simulated module temperature respectively.
- **beta_voc_module**, **beta_voc_string**: beta_voc for a module and a string respectively.
- **alpha_isc_module_rated**, **alpha_isc_module_meas**: rated and measured module alpha_isc.