
PV-DER Simulation Utility

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Contents:

1	PV-DER package	3
1.1	DER models	3
1.2	DER Simulation	13
2	License	19
3	Indices and tables	21
	Python Module Index	23
	Index	25

This is a reference for all the classes and methods available in PV-DER Simulation Utility.

1.1 DER models

1.1.1 pvder.DER_components_three_phase

Three phase PV-DER components.

```
class pvder.DER_components_three_phase.SolarPVDERThreePhase (events,          con-
                                                              figFile=None,
                                                              **kwargs)
```

Bases: pvder.DER_components.PVModule, pvder.DER_components.SolarPVDER

Class for describing a Solar Photo-voltaic Distributed Energy Resource consisting of panel, converters, and control systems. Attributes: count (int): Number of instances of *SolarPVDERThreePhase*. n_ODE (int): Number of ODE's.

Creates an instance of *SolarPV_DER_ThreePhase*. :param events: An instance of *SimulationEvents*. :type events: *SimulationEvents* :param gridModel: An instance of 'Gridl'(only need to be supplied for stand alone simulation). :type gridModel: *Grid* :param powerRating: A scalar specifying the rated power (VA) of the DER. :type powerRating: float :param VrmsRating: A scalar specifying the rated RMS L-G voltage (V) of the DER. :type VrmsRating: float :param ia0,xa0,ua0: Initial value of inverter states in p.u. of the DER instance. :type ia0,xa0,ua0: complex :param xDC0,xQ0,xPLL0,wte0: Initial value of inverter states in the DER instance. :type xDC0,xQ0,xPLL0,wte0: float :param gridVolatePhaseA,gridVolatePhaseA,gridVolatePhaseA: Initial voltage phasor (V) at PCC - LV side from external program (only need to be supplied if model is not stand alone). :type gridVolatePhaseA,gridVolatePhaseA,gridVolatePhaseA: float :param standAlone: Specify if the DER instance is a stand alone simulation or part of a larger simulation. :type standAlone: bool :param STEADY_STATE_INITIALIZATION: Specify whether states in the DER instance will be initialized to steady state values. :type STEADY_STATE_INITIALIZATION: bool :param allow_unbalanced_m: Allow duty cycles to take on unbalanced values during initialization (default: False). :type allow_unbalanced_m: bool :param derConfig: Configuration parameters that may be supplied from an external program. :type derConfig: dict :param identifier: An identifier that can be used to name the instance (default: None). :type identifier: str

Raises

- `ValueError` – If parameters corresponding to *Sinverter Rated* are not available.

- `ValueError` – If rated DC link voltage is not sufficient.

`Irms_calc()`
Inverter current - RMS

`ODE_model(y, t)`
Derivatives for the equation.

`S_G_calc()`
Power absorbed/produced by grid voltage source.

`S_PCC_calc()`
Power output at PCC LV side

`S_calc()`
Inverter apparent power output

`S_load1_calc()`
Power absorbed by load at PCC LV side.

`Vabrms_calc()`
PCC LV side voltage - line to line RMS

`Vrms_calc()`
PCC LV side voltage - RMS

`Vrms_min_calc()`
PCC LV side voltage - RMS

`Vtabrms_calc()`
Inverter terminal voltage - line to line RMS

`Vtrms_calc()`
Inverter terminal voltage - RMS

`jac_ODE_model(y, t)`
Jacobian for the system of ODE's.

`update_RMS()`
Update RMS voltages.

`update_inverter_frequency(t)`
Update d-q quantities.

`update_inverter_states(ia, xa, ua, ib, xb, ub, ic, xc, uc, Vdc, xDC, xQ, xPLL, wte)`
Update inverter states

`update_iref(t)`
Update reference reference current.

`update_power()`
Update RMS voltages.

`update_voltages()`
Update voltages.

`y0`
List of initial states

1.1.2 `pvder.DER_components_single_phase`

Single phase PV-DER code.


```
class pvder.DER_components_single_phase.SolarPVDERSinglePhase(events, con-  
                                                                figFile=None,  
                                                                **kwargs)
```

Bases: pvder.DER_components.PVModule, pvder.DER_components.SolarPVDER

Class for describing a Solar Photo-voltaic Distributed Energy Resource consisting of panel, converters, and control systems.

count

Number of instances of *SolarPVDERSinglePhase*.

Type int

n_ODE

Number of ODE's.

Type int

Creates an instance of *SolarPV_DER_SinglePhase*. Args: *events* (SimulationEvents): An instance of *SimulationEvents*. *gridModel* (Grid): An instance of 'Grid'(only need to be supplied for stand alone simulation). *powerRating* (float): A scalar specifying the rated power (VA) of the DER. *VrmsRating* (float): A scalar specifying the rated RMS L-G voltage (V) of the DER. *ia0,xa0,ua0* (complex): Initial value of inverter states in p.u. of the DER instance. *xDC0,xQ0,xPLL0,wte0* (float): Initial value of inverter states in the DER instance. *gridVolatePhaseA,gridVolatePhaseA,gridVolatePhaseA* (float): Initial voltage phasor (V) at PCC - LV side from external program (only need to be supplied if model is not stand alone). *standAlone* (bool): Specify if the DER instance is a stand alone simulation or part of a larger simulation. *steadyStateInitialization* (bool): Specify whether states in the DER instance will be initialized to steady state values. *allowUnbalancedM* (bool): Allow duty cycles to take on unbalanced values during initialization (default: False). *derConfig* (dict): Configuration parameters that may be supplied from an external program. *identifier* (str): An identifier that can be used to name the instance (default: None).

Raises: ValueError: If parameters corresponding to *Sinverter_rated* are not available. ValueError: If rated DC link voltage is not sufficient.

Irms_calc()

Inverter current - RMS

ODE_model (*y, t*)

System of ODE's defining the dynamic DER model. :param *y*: Initial conditions for the states.. :type *y*: list of float :param *t*: Simulation time in seconds. :type *t*: float

Returns Derivates for the system of ODE's.

Return type result (list of float)

S_G_calc()

Power absorbed/produced by grid voltage source.

S_PCC_calc()

Power output at PCC LV side

S_calc()

Inverter apparent power output

S_load1_calc()

Power absorbed by load at PCC LV side.

Vabrms_calc()

PCC LV side voltage - line to lineRMS

Vrms_calc()

PCC LV side voltage - RMS

Vtrms_calc ()
 Inverter terminal voltage -RMS

jac_ODE_model (y, t)
 Jacobian for the system of ODE's. :param y: Initial conditions for the states.. :type y: list of float :param t: Simulation time in seconds. :type t: float

Returns An array containing the elements of the Jacobian.

Return type result (array of float)

update_RMS ()
 Update RMS voltages.

update_inverter_frequency (t)
 Update inverter PLL frequency. :param t: Simulation time in seconds. :type t: float

update_inverter_states (ia, xa, ua, Vdc, xDC, xQ, xPLL, wte)
 Update inverter states :param ia: Inverter phase a current. :type ia: complex :param xa: Inverter controller state. :type xa: complex :param ua: Inverter controller state. :type ua: complex :param Vdc: DC link voltage. :type Vdc: float

update_iref (t)
 Update reference reference current.

update_power ()
 Update RMS voltages.

update_voltages ()
 Update voltages.

y0
 List of initial states

1.1.3 pvder.DER_check_and_initialize

Code for initializing and validating PV-DER model instances.

class pvder.DER_check_and_initialize.**PVDER_SetupUtilities**
 Bases: pvder.grid_components.BaseValues
 Utility class for error checking during model initialization.

attach_grid_model (DER_arguments)
 Attach a grid model to the PV-DER instance. :param grid_model: An instance of *GridModel*.

Returns Description of return value

Return type bool

check_DER_config (DER_config, DER_id)
 Check DER config.

check_circuit_parameters ()
 Method to check whether inverter circuit parameter's are feasible.

check_config_file (config_file, config_dict)
 Check whether DER config file contains necessary fields.

check_jacobian (t=0.0)
 Compare analytical and numerical Jacobian of the ODE model.

check_voltage()
Method to check whether inverter voltage ratings are feasible. :raises: ValueError – If any of the specified voltage ratings is infeasible.

circuit_parameters = {}

controller_gains = {}

creation_message()
Message after PV-DER instance was created.

initialize_DER_model()
Initialize DER ratings.

Parameters DER_arguments (dict) – Key word arguments.

Raises ValueError – If specified parameters corresponding to *parameter_ID* is not available.

initialize_Iac()
Initialize AC side currents.

initialize_Sinverter()
Initialize inverter power rating.

initialize_Vac()
Initialize AC side voltages.

initialize_Vdc()
Initialize DC side voltages.

initialize_basic_options()
Initialize basic options

initialize_basic_specs()
Initialize number of ODEs and phases

initialize_circuit_parameters()
Initialize C, Lf, and Rf parameters.

initialize_controller_gains()
Initialize controller settings.

initialize_derived_quantities()
Initialize quantities other than states.

initialize_grid_measurements (DER_arguments)
Initialize inverter states. :param gridVoltagePhaseA: Value of gridVoltagePhaseA :type gridVoltagePhaseA: complex :param gridVoltagePhaseB: Value of gridVoltagePhaseB :type gridVoltagePhaseB: complex :param gridVoltagePhaseC: Value of gridVoltagePhaseC :type gridVoltagePhaseC: complex :param gridFrequency: Value of gridFrequency :type gridFrequency: float

initialize_inverter_ratings()
Initialize inverter voltage and power ratings.

initialize_jacobian()
Create a Jacobian matrix with zero values.

initialize_states (DER_arguments)
Initialize inverter states.

Parameters

- **ia0 (float)** – Initial current
- **xa0 (float)** – Initial controller state

- `ua0 (float)` – Initial controller state

```
inverter_ratings = {}  
modify_DER_parameters (parameter_ID)  
    Modify the DER parameters to parameters corresponding to the given parameter ID. :param parameter_ID:  
    User specified parameter ID (can be None). :type parameter_ID: str  
  
module_parameters = {}  
power_error_calc (x)  
    Function for power.  
  
solver_spec = {'SLSQP': {'disp': True, 'ftol': 1e-10, 'maxiter': 10000}, 'nelder-mead'  
steady_state_calc ()  
    Find duty cycle and inverter current that minimize steady state error and return steady state values.  
  
steadystate_solver = 'SLSQP'  
steadystate_values = {}  
  
update_DER_config (DER_config, DER_parent_config, DER_arguments, DER_id, DER_parent_id)  
    Update PV-DER design.  
  
update_DER_parameter (DER_config, DER_parent_config, DER_arguments, DER_id,  
                        DER_parent_id, DER_component, DER_parameter)  
    Update DER config using both config file and arguments.
```

1.1.4 pvder.DER_utilities

Code containing utilities used by PV-DER model instances.

```
class pvder.DER_utilities.PVDER_ModelUtilities  
    Bases: pvder.grid_components.BaseValues, pvder.utility_classes.Utilities  
    Utility class for single phase and three phase PV-DER model.  
  
    DO_EXTRA_CALCULATIONS = False  
    MPPT_ENABLE = False  
    MPP_table ()  
        Method to output Vdc reference corresponding to MPP at different insolation levels values.  
    PRINT_INLINE = False  
    Qref_EXTERNAL = False  
    RAMP_ENABLE = False  
    RAMP_FLAG = False  
    S_PCCph_calc (vph, iph)  
        Inverter apparent power output - phase a/b/c  
    VERBOSE = False  
    Vdc_actual  
        Actual DC link voltage. :returns: DC link voltage in Volts. :rtype: float  
    Vdc_ref_counter = 0  
    Vdc_ref_list = []
```

Vdc_ref_ramp (*tstart*, *Vdc_ref_target*)
 Create a ramp signal for voltage reference that ramps at 1 V/s. :param tstart: A scalar specifying start time of ramp in seconds. :type tstart: float :param Vdc_ref_target: A scalar specifying target Vdc reference seconds in volts. :type Vdc_ref_target: float

Vdc_ref_total = 0

add_Vdc_ref (*t*, *Vdc_ref*)
 Add new solar event.

create_parameter_dict (*parameter_ID*)
 Create a DER mode.

del_Vdc_ref = 2.0

del_t_Vdc_ref = 0.5

get_Vdc_ref (*t*)
 Output Vdc reference.

get_default_parameter_ID ()
 Return default parameter ID.

get_iref_actual (*t*, *ia_ref_command*, *iaR_ref_previous*, *iaI_ref_previous*)
 Update reference reference current.

get_parameter_dictionary (*parameter_type*, *parameter_ID*, *SHOW_DICTIONARY=True*)
 Return parameter dictionary for specified parameter type and parameter ID. :param parameter_type: Specify type of parameter. :type parameter_type: str :param parameter_ID: Specify parameter ID or 'all'. :type parameter_ID: str :param SHOW_DICTIONARY: Print the dictionary. :type SHOW_DICTIONARY: bool

Returns Parameters and their values

Return type dict

get_ramp_limited_iref (*t*, *ia_ref_command*)
 Update reference reference current.

ia_ref_activepower_control ()
 Phase A current reference for constant Vdc

ia_ref_calc ()
 Phase A current reference

ib_ref_activepower_control ()
 Phase B current reference for constant Vdc

ib_ref_calc ()
 Phase B current reference

ic_ref_activepower_control ()
 Phase C current reference for constant Vdc

ic_ref_calc ()
 Phase C current reference

initialize_parameter_dict (*parameter_ID*, *source_parameter_ID*)
 Initialize a new parameter dictionary with values from an existing parameter dictionary.

iphload1_calc (*vph*)
 Current consumed by load connected at PCC LV side - Phase A/B/C.

load_parameter_dictionary (*file_name*)
 Load parameter dictionary from saved file.

```

m_limit = 1.0

ma
    Phase A duty cycle. :returns: Duty cycle. :rtype: complex

mb
    Phase B duty cycle. :returns: Duty cycle. :rtype: complex

mc
    Phase C duty cycle. :returns: Duty cycle. :rtype: complex

n_steps = 0

ramp_del_t = 0.5

ramp_list = []

reset_reference_counters()
    Reset counter for reference change events.

save_parameter_dictionary(parameter_ID,                                save_format='pickle',
                             SHOW_DICTIONARY=False)
    Save parameter dictionary.

set_Vdc_ref()
    Return the correct Vdc reference voltage.

show_PV_DER_parameters(parameter_type='inverter_ratings')
    Display rated values. :param parameter_type: A string ('in-
    verter_ratings','controller_gains','circuit_parameters') specifying the parameter to be displayed.
    :type parameter_type: str

show_PV_DER_states(quantity='voltage')
    Display values of states in the DER model quantities. Arguments
    quantity: A string ('voltage','current','power','duty cycle') specifying the electrical quantity to
    be displayed.

show_parameter_dictionaries()
    Show all parameter dictionary types and their ID's.

show_parameter_types()
    Show all parameters within all parameter dictionary types.

show_references()
    Print references.

update_Ppv(t)
    Update PV module power output based on solar events and DC link voltage.

update_Qref(t)
    Update reactive power set-point.

update_Vdc_ref(t)
    Update DC link voltage reference.

update_Zload1(t)
    Update load impedance at PCC-LV side.

update_parameter_dict(parameter_ID, parameter_type, parameter_dict)
    Update parameters.

use_frequency_estimate = False

```

```

va_calc()
    PCC - LV side - Phase A

validate_model (PRINT_ERROR=True)
    Compare error between RMS quantities and Phasor quantities.

vb_calc()
    PCC - LV side - Phase B

vc_calc()
    PCC - LV side - Phase C

vta_calc()
    Inverter terminal voltage - Phase A

vtb_calc()
    Inverter terminal voltage - Phase B

vtc_calc()
    Inverter terminal voltage - Phase C

we_calc()
    Calculate inverter frequency from PLL.

wgrid_calc (t)
    Frequency of grid voltage source.

wgrid_estimate (t)
    Estimate frequency from phasor angle.

wgrid_estimate_calc (t, phi_new, phi_previous)
    Estimate frequency.

```

1.1.5 pvder.DER_features

Code for features inside PV-DER model instances.

```

class pvder.DER_features.PVDER_SmartFeatures
    Bases: object

    Class for describing smart inverter inverter features of PV-DER.

    DER_CONNECTED = True

    DER_MOMENTARY_CESSATION = False

    DER_TRIP = False

    DER_disconnect()
        Function to disconnect PV-DER from grid.

    DER_disconnect_logic (t)
        Logic for disconnecting/deenergizing DER from grid.

    DER_reconnect_logic (t)
        Logic used to decide reconnection.

    FRT (t)
        Frequency ride through and trip logic.

    FRT_INSTANTANEOUS_TRIP

    FRT_initialize()
        Initialize LFRT and HFRT settings.

```

HVRT (*t*)
Function to implement HVRT ridethrough and trip logic.

LVRT (*t*)
Function to implement LVRT ridethrough and trip logic.

Q_Volt_VAR_absorb (*Vrms_measured*)
Calculate reactive power for Volt-VAR control.

Q_Volt_VAR_inject (*Vrms_measured*)
Calculate reactive power for Volt-VAR control.

Qlimit_calc ()
Calculate maximum Q reference.

RT_initialize ()
Initialize VRT and FRT settings.

VOLT_VAR_ENABLE = False

VOLT_VAR_FLAG = False

VOLT_WATT_ENABLE = False

VOLT_WATT_FLAG = False

VRT_initialize ()
Initialize LVRT and HVRT settings.

V_threshold_high_limit = 1.5

Volt_VAR_absorb_range (*Vrms_measured, del_V=0.0*)
Check if voltage in volt-VAR operating range.

Volt_VAR_inject_range (*Vrms_measured, del_V=0.0*)
Check if voltage in volt-VAR operating range.

Volt_VAR_logic (*t*)
Volt-VAR.

check_HFRT_settings ()
Sanity check for HFRT settings.

check_LFRT_settings ()
Sanity check for LFRT settings.

check_RT_config ()
Check whether the config file is good.

check_VRT_settings ()
Sanity check for VRT settings.

check_anomaly ()
Check if voltage anomaly was detected.

disconnect_or_reconnect (*t*)
Check flags and either disconnect or reconnect DER.

f_ref = 60.0

get_Vrms_measured ()
Get Vrms measurement

initialize_Volt_VAR ()
Initialize the Volt-VAR controller settings.


```
DEBUG_CONTROLLERS = False
DEBUG_CURRENTS = False
DEBUG_PLL = False
DEBUG_POWER = False
DEBUG_SIMULATION = False
DEBUG_SOLVER = False
DEBUG_VOLTAGES = False

ODE_model(y, t)
    Combine all derivatives.

check_jac_availability()
    Check if Jacobian matrix is available.

collect_full_trajectory(solution)
    Collect full solution from solver.

collect_last_states()
    Collect states at last time step.

collect_solution(solution, t=None)
    Collect solution.

collect_states(solution)
    Collect states from ode solution.

count = 0

debug_simulation(t)
    Print to terminal for debugging.

get_trajectories()
    Return trajectories as a dictionary.

initialize_y0_t()
    Initialize y0_t.

invert_arrays()
    Inverter arrays before usage by plots.

jac_ODE_model(y, t)
    Combine all derivatives.

jac_list = ['SolarPVDERThreePhase', 'SolarPVDESinglePhase', 'SolarPVDERThreePhaseBalanc

reset_stored_trajectories()
    Reset for plotting.

run_simulation(gridVoltagePhaseA=None, gridVoltagePhaseB=None, gridVoltagePhaseC=None,
               y0=None, t=None)
    Call the ODE solver and collect states.

show_simulation_time()
    Show simulation time.

tInc = 0.001

tStart = 0.0

t_calc()
    Vector of time steps for simulation
```

```

time_series_PCC_HV_side_voltage()
    Calculate time series PCC voltage.

time_series_PCC_LV_side_voltage()
    Calculate time series PCC voltage.

time_series_PLL()
    Calculate time series PLL and d-q quantities.

time_series_Ppv()
    Calculate time series Solar PV power output.

time_series_RMS()
    Calculate time series RMS quantities.

time_series_S()
    Calculate time series apparent power.

time_series_Zload1(tOverride=None)
    Calculate time series load impedance.

time_series_duty_cycle()
    Calculate time series PCC voltage.

time_series_inv_terminal_voltage()
    Calculate time series inverter terminal voltage.

time_series_phase_angle()
    Calculate time series phase angle between grid and inverter voltage.

time_series_power_transfer()
    Calculate time series power transfer between grid and PCC.

time_series_standalone_grid()
    Time series grid voltage and frequency for standalone model.

update_grid_measurements(gridVoltagePhaseA, gridVoltagePhaseB, gridVoltagePhaseC)
    Update grid voltage and frequency in non-standalone model. :param gridVoltagePhaseA: Value of
    gridVoltagePhaseA :type gridVoltagePhaseA: complex :param gridVoltagePhaseB: Value of gridVoltagePhaseB :type gridVoltagePhaseB: complex :param gridVoltagePhaseC: Value of gridVoltagePhaseC :type gridVoltagePhaseC: complex

y0
    Combine all initial conditions from solution.

```

1.2.2 pvder.simulation_events

Manage simulation events.

```

class pvder.simulation_events.SimulationEvents(events_spec=None, SO-
                                                LAR_EVENT_ENABLE=True,
                                                GRID_EVENT_ENABLE=True,
                                                LOAD_EVENT_ENABLE=True, ver-
                                                bosity='INFO', identifier='')

```

Bases: `pvder.utility_classes.Utilities`

Utility class for events.

Creates an instance of *SimulationEvents*. :param SOLAR_EVENT_ENABLE: A boolean to enable solar insolation events. :param GRID_EVENT_ENABLE: A boolean to enable grid voltage or frequency events. :param LOAD_EVENT_ENABLE: A boolean to enable load change events at PCC-LV side.

Tactual_default = 298.15

Zload1_actual_default = (10000000+0j)

add_grid_event (*T*, *Vgrid=1.0*, *Vgrid_angle=0.0*, *fgrid=60.0*)
Add new grid event. :param *T*: A scalar specifying start time of grid event in seconds. :type *T*: float :param *Vgrid*: A scalar specifying grid voltage magnitude in fraction. :type *Vgrid*: float :param *Vgrid_angle*: A scalar specifying grid voltage angle in radians. :type *Vgrid_angle*: float :param *fgrid*: A scalar specifying grid frequency in Hz. :type *fgrid*: float

add_load_event (*T*, *Zload1_actual=(10000000+0j)*)
Add new load event. :param *T*: A scalar specifying start time of load event in seconds. :param *Zload1_actual*: A complex scalar specifying load in ohm.

add_solar_event (*T*, *Sinsol=100.0*, *Tactual=298.15*)
Add new solar event. :param *T*: A scalar specifying start time of solar event in seconds. :type *T*: float :param *Sinsol*: A scalar specifying solar insolation in percentage. :type *Sinsol*: float :param *Tactual*: A scalar specifying module temperature in Kelvin. :type *Tactual*: float

count = 0

create_random_events (*t_event_start*, *t_event_end*, *t_event_step*, *events_type=['insolation', 'voltage']*)
Create random events of specified types.

create_random_insolation_events (*t_event*)
Create random voltage event at specified time.

create_random_voltage_events (*t_event*)
Create random voltage event at specified time.

del_t_event = 0.001

grid_events (*t*)
Generate grid event during simulation at specified time. :param *t*: A scalar specifying the time (s). :type *t*: float

insolation_ramp (*tstart*, *tstop*, *Sinsol_target*, *tstep=0.25*)
Create a ramp signal. :param *tstart*: A scalar specifying start time of solar insolation event in seconds. :param *tstop*: A scalar specifying stop time of solar insolation event in seconds. :param *Sinsol_target*: A scalar specifying target solar insolation at 'tstop' in percentage. :param *tstep*: A scalar specifying time step size.

load_events (*t*)
Generate load event at PCC LV side during simulation. :param *t*: A scalar specifying the time (s). :type *t*: float

override_angle = True

remove_grid_event (*T*)
Remove grid event at 'T'.

remove_load_event (*T=None*, *REMOVE_ALL=False*)
Remove solar event at 'T'

remove_solar_event (*T=None*, *REMOVE_ALL=False*)
Remove solar event at 'T'.

reset_event_counters ()
Reset event counts.

show_events ()
Print all the simulation events.

simulation_events_list

List of all simulation events.

solar_events (*t*)

Generate solar event during simulation at specified time. :param *t*: A scalar specifying the time (s). :type *t*: float

update_event_totals ()

Update event counts.

update_events_spec (*events_spec*)

Update the `_events_spec` dictionary.

voltage_ramp (*tstart*, *tstop*, *vg_target*, *tstep=0.5*)

Create a ramp signal for grid voltage. :param *tstart*: A scalar specifying start time of grid voltage event in seconds. :param *tstop*: A scalar specifying stop time of grid voltage event in seconds. :param *vg_target*: A scalar specifying target grid voltage at '*tstop*' in fraction. :param *tstep*: A scalar specifying time step size (optional).

1.2.3 pvder.simulation_utilities

Manage simulation results and ODE solver.

```
class pvder.simulation_utilities.SimulationResults (simulation, figure_index=1,
                                                    PER_UNIT=True, font_size=18,
                                                    PLOT_TITLE=True, SO-
                                                    LUTION_TIME=True, ver-
                                                    bosity='INFO', identifier=None)
```

Bases: `pvder.utility_classes.Utilities`

Utility class for simulation results.

Creates an instance of *SimulationResults*. Args: *simulation*: An instance of *GridSimulation*. *figure_index*: An integer specifying the figure index. *font_size*: An integer specifying the font size to be used withing plots. *PLOT_TITLE*: A boolean specifying whether the title will be displayed in plots. *verbosity*: A string specifying the verbosity level (DEBUG,INFO,WARNING,ERROR).

SAVE_PLOT_JPEG = **False**

SAVE_PLOT_SVG = **False**

available_plot_types = ['power', 'active_power', 'active_power_Ppv_Pac_PCC', 'active_p

change_units ()

Change units from per unit to S.I. or vice versa.

compare_with_external (*external_time_values*, *external_plot_values*, *external_plot_legends*,
plot_type='power')

Compare with external simulation.

count = 0

figure_DPI = 1200

group_quantities_for_plotting (*plot_type*)

Plot power from simulation. Args: *plot_type* (string): The quantities to be plotted.

Raises `ValueError` – If *plot_type* is not available.

parameters = {'figure': {'height': 8, 'width': 8}}

plot_DER_simulation (*plot_type='power'*)

Plot desired electrical quantity from simulation. Args: *plot_type* (str): Specify type of plot (to see available plot types use `SimulationResults.available_plot_types`).

plot_multiple (*time_values, plot_values, legends, plot_title, y_labels*)

Function to plot multiple time series on same plot.

save_plot (*plot_object, plot_name='results'*)

Save the plots.

class `pvder.simulation_utilities.SimulationUtilities`

Bases: `object`

Utility class for dynamic simulations.

ODE_model_ode (*t, y*)

” Combine all derivatives when using ode method

call_ODE_solver (*derivatives, jacobian, y, t*)

Call the SciPy ODE solver.

call_ode_solver ()

Use the SciPy ode solver.

call_odeint_solver (*derivatives, jacobian, y, t*)

Use the SciPy odeint solver.

check_simulation (*infodict, t*)

Check whether the ODE solver failed at any time step.

initialize_solver (*solver_type, t0=0.0*)

Initialize an integrator.

jac_ODE_model_ode (*t, y*)

Combine all derivatives.

max_steps = 1000

solver_list = ['odeint', 'ode-vode-bdf']

CHAPTER 2

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CHAPTER 3

Indices and tables

- `genindex`
- `modindex`
- `search`

p

- `pvder.DER_check_and_initialize`, [6](#)
- `pvder.DER_components_single_phase`, [4](#)
- `pvder.DER_components_three_phase`, [3](#)
- `pvder.DER_features`, [11](#)
- `pvder.DER_utilities`, [8](#)
- `pvder.dynamic_simulation`, [13](#)
- `pvder.simulation_events`, [15](#)
- `pvder.simulation_utilities`, [17](#)

A

`add_grid_event()` (`pvder.simulation_events.SimulationEvents`
method), 16
`add_load_event()` (`pvder.simulation_events.SimulationEvents`
method), 16
`add_solar_event()`
(`pvder.simulation_events.SimulationEvents`
method), 16
`add_Vdc_ref()` (`pvder.DER_utilities.PVDER_ModelUtilities`
method), 9
`attach_grid_model()`
(`pvder.DER_check_and_initialize.PVDER_SetupUtilities`
method), 6
`available_plot_types`
(`pvder.simulation_utilities.SimulationResults`
attribute), 17

C

`call_ODE_solver()`
(`pvder.simulation_utilities.SimulationUtilities`
method), 18
`call_ode_solver()`
(`pvder.simulation_utilities.SimulationUtilities`
method), 18
`call_odeint_solver()`
(`pvder.simulation_utilities.SimulationUtilities`
method), 18
`change_units()` (`pvder.simulation_utilities.SimulationResults`
method), 17
`check_anomaly()` (`pvder.DER_features.PVDER_SmartFeatures`
method), 12
`check_circuit_parameters()`
(`pvder.DER_check_and_initialize.PVDER_SetupUtilities`
method), 6
`check_config_file()`
(`pvder.DER_check_and_initialize.PVDER_SetupUtilities`
method), 6
`check_DER_config()`
(`pvder.DER_check_and_initialize.PVDER_SetupUtilities`
method), 6
`check_HFRT_settings()`
(`pvder.DER_features.PVDER_SmartFeatures`
method), 12
`check_jac_availability()`
(`pvder.dynamic_simulation.DynamicSimulation`
method), 14
`check_jacobian()` (`pvder.DER_check_and_initialize.PVDER_SetupUtilities`
method), 6
`check_LFRT_settings()`
(`pvder.DER_features.PVDER_SmartFeatures`
method), 12
`check_simulation()`
(`pvder.simulation_utilities.SimulationUtilities`
method), 18
`check_voltage()` (`pvder.DER_check_and_initialize.PVDER_SetupUtilities`
method), 6
`check_VRT_settings()`
(`pvder.DER_features.PVDER_SmartFeatures`
method), 12
`circuit_parameters`
(`pvder.DER_check_and_initialize.PVDER_SetupUtilities`
attribute), 7
`collect_full_trajectory()`
(`pvder.dynamic_simulation.DynamicSimulation`
method), 14
`collect_last_states()`
(`pvder.dynamic_simulation.DynamicSimulation`
method), 14
`collect_solution()`
(`pvder.dynamic_simulation.DynamicSimulation`
method), 14
`collect_states()` (`pvder.dynamic_simulation.DynamicSimulation`
method), 14
`compare_with_external()`
(`pvder.simulation_utilities.SimulationResults`
method), 17

controller_gains (pvder.DER_check_and_initialize.PVDER_SetupUtilities (pvder.DER_features.PVDER_SmartFeatures attribute), 7	method), 11
count (pvder.DER_components_single_phase.SolarPVDER_SinglePhase attribute), 5	(pvder.DER_features.PVDER_SmartFeatures method), 11
count (pvder.dynamic_simulation.DynamicSimulation attribute), 14	DER_MOMENTARY_CESSATION (pvder.DER_features.PVDER_SmartFeatures attribute), 11
count (pvder.simulation_events.SimulationEvents attribute), 16	DER_reconnect_logic (pvder.DER_features.PVDER_SmartFeatures method), 11
count (pvder.simulation_utilities.SimulationResults attribute), 17	DER_TRIP (pvder.DER_features.PVDER_SmartFeatures attribute), 11
create_parameter_dict (pvder.DER_utilities.PVDER_ModelUtilities method), 9	disconnect_or_reconnect (pvder.DER_features.PVDER_SmartFeatures method), 12
create_random_events (pvder.simulation_events.SimulationEvents method), 16	DO_EXTRA_CALCULATIONS (pvder.DER_utilities.PVDER_ModelUtilities attribute), 8
create_random_insolation_events (pvder.simulation_events.SimulationEvents method), 16	DynamicSimulation (class in pvder.dynamic_simulation), 13
create_random_voltage_events (pvder.simulation_events.SimulationEvents method), 16	
creation_message (pvder.DER_check_and_initialize.PVDER_SetupUtilities method), 7	
D	
DEBUG_CONTROLLERS (pvder.dynamic_simulation.DynamicSimulation attribute), 13	figure_DPI (pvder.simulation_utilities.SimulationResults attribute), 17
DEBUG_CURRENTS (pvder.dynamic_simulation.DynamicSimulation attribute), 14	FRT (pvder.DER_features.PVDER_SmartFeatures method), 11
DEBUG_PLL (pvder.dynamic_simulation.DynamicSimulation attribute), 14	FRT_initialize (pvder.DER_features.PVDER_SmartFeatures method), 11
DEBUG_POWER (pvder.dynamic_simulation.DynamicSimulation attribute), 14	FRT_INSTANTANEOUS_TRIP (pvder.DER_features.PVDER_SmartFeatures attribute), 11
DEBUG_SIMULATION (pvder.dynamic_simulation.DynamicSimulation attribute), 14	
debug_simulation (pvder.dynamic_simulation.DynamicSimulation method), 14	get_default_parameter_ID (pvder.DER_utilities.PVDER_ModelUtilities method), 9
DEBUG_SOLVER (pvder.dynamic_simulation.DynamicSimulation attribute), 14	get_iref_actual (pvder.DER_utilities.PVDER_ModelUtilities method), 9
DEBUG_VOLTAGES (pvder.dynamic_simulation.DynamicSimulation attribute), 14	get_parameter_dictionary (pvder.DER_utilities.PVDER_ModelUtilities method), 9
del_t_event (pvder.simulation_events.SimulationEvents attribute), 16	get_ramp_limited_iref (pvder.DER_utilities.PVDER_ModelUtilities method), 9
del_t_Vdc_ref (pvder.DER_utilities.PVDER_ModelUtilities attribute), 9	get_trajectories (pvder.dynamic_simulation.DynamicSimulation method), 14
del_Vdc_ref (pvder.DER_utilities.PVDER_ModelUtilities attribute), 9	get_Vdc_ref (pvder.DER_utilities.PVDER_ModelUtilities method), 9
DER_CONNECTED (pvder.DER_features.PVDER_SmartFeatures attribute), 11	

F

G

`get_Vrms_measured()` (*pvder.DER_features.PVDER_SmartFeatures* *method*), 12
`grid_events()` (*pvder.simulation_events.SimulationEvents* *method*), 16
`group_quantities_for_plotting()` (*pvder.simulation_utilities.SimulationResults* *method*), 17
H
`HVRT()` (*pvder.DER_features.PVDER_SmartFeatures* *method*), 12
I
`ia_ref_activepower_control()` (*pvder.DER_utilities.PVDER_ModelUtilities* *method*), 9
`ia_ref_calc()` (*pvder.DER_utilities.PVDER_ModelUtilities* *method*), 9
`ib_ref_activepower_control()` (*pvder.DER_utilities.PVDER_ModelUtilities* *method*), 9
`ib_ref_calc()` (*pvder.DER_utilities.PVDER_ModelUtilities* *method*), 9
`ic_ref_activepower_control()` (*pvder.DER_utilities.PVDER_ModelUtilities* *method*), 9
`ic_ref_calc()` (*pvder.DER_utilities.PVDER_ModelUtilities* *method*), 9
`initialize_basic_options()` (*pvder.DER_check_and_initialize.PVDER_SetupUtilities* *method*), 7
`initialize_basic_specs()` (*pvder.DER_check_and_initialize.PVDER_SetupUtilities* *method*), 7
`initialize_circuit_parameters()` (*pvder.DER_check_and_initialize.PVDER_SetupUtilities* *method*), 7
`initialize_controller_gains()` (*pvder.DER_check_and_initialize.PVDER_SetupUtilities* *method*), 7
`initialize_DER_model()` (*pvder.DER_check_and_initialize.PVDER_SetupUtilities* *method*), 7
`initialize_derived_quantities()` (*pvder.DER_check_and_initialize.PVDER_SetupUtilities* *method*), 7
`initialize_grid_measurements()` (*pvder.DER_check_and_initialize.PVDER_SetupUtilities* *method*), 7
`initialize_Iac()` (*pvder.DER_check_and_initialize.PVDER_SetupUtilities* *method*), 7
`initialize_inverter_ratings()` (*pvder.DER_check_and_initialize.PVDER_SetupUtilities* *method*), 7
`initialize_jacobian()` (*pvder.DER_check_and_initialize.PVDER_SetupUtilities* *method*), 7
`initialize_parameter_dict()` (*pvder.DER_utilities.PVDER_ModelUtilities* *method*), 9
`initialize_Sinverter()` (*pvder.DER_check_and_initialize.PVDER_SetupUtilities* *method*), 7
`initialize_solver()` (*pvder.simulation_utilities.SimulationUtilities* *method*), 18
`initialize_states()` (*pvder.DER_check_and_initialize.PVDER_SetupUtilities* *method*), 7
`initialize_Vac()` (*pvder.DER_check_and_initialize.PVDER_SetupUtilities* *method*), 7
`initialize_Vdc()` (*pvder.DER_check_and_initialize.PVDER_SetupUtilities* *method*), 7
`initialize_Volt_VAR()` (*pvder.DER_features.PVDER_SmartFeatures* *method*), 12
`initialize_y0_t()` (*pvder.dynamic_simulation.DynamicSimulation* *method*), 14
`insolation_ramp()` (*pvder.simulation_events.SimulationEvents* *method*), 16
`invert_arrays()` (*pvder.dynamic_simulation.DynamicSimulation* *method*), 14
`inverter_ratings` (*pvder.DER_check_and_initialize.PVDER_SetupUtilities* *attribute*), 8
`inload1_calc()` (*pvder.DER_utilities.PVDER_ModelUtilities* *method*), 9
`Irms_calc()` (*pvder.DER_components_single_phase.SolarPVDERSinglePhase* *method*), 5
`Irms_calc()` (*pvder.DER_components_three_phase.SolarPVDERThreePhase* *method*), 4
J
`jac_list` (*pvder.dynamic_simulation.DynamicSimulation* *attribute*), 14
`jac_ODE_model()` (*pvder.DER_components_single_phase.SolarPVDERSinglePhase* *method*), 6
`jac_ODE_model()` (*pvder.DER_components_three_phase.SolarPVDERThreePhase* *method*), 4
`jac_ODE_model()` (*pvder.dynamic_simulation.DynamicSimulation* *method*), 14
`jac_ODE_model_ode()` (*pvder.simulation_utilities.SimulationUtilities* *method*), 18

L

load_events() (pvder.simulation_events.SimulationEvents
method), 16

load_parameter_dictionary()
(pvder.DER_utilities.PVDER_ModelUtilities
method), 9

LVRT() (pvder.DER_features.PVDER_SmartFeatures
method), 12

M

m_limit (pvder.DER_utilities.PVDER_ModelUtilities
attribute), 9

ma (pvder.DER_utilities.PVDER_ModelUtilities at-
tribute), 10

max_steps (pvder.simulation_utilities.SimulationUtilities
attribute), 18

mb (pvder.DER_utilities.PVDER_ModelUtilities at-
tribute), 10

mc (pvder.DER_utilities.PVDER_ModelUtilities at-
tribute), 10

modify_DER_parameters()
(pvder.DER_check_and_initialize.PVDER_SetupUtilities
method), 8

module_parameters
(pvder.DER_check_and_initialize.PVDER_SetupUtilities
attribute), 8

MPP_table() (pvder.DER_utilities.PVDER_ModelUtilities
method), 8

MPPT_ENABLE (pvder.DER_utilities.PVDER_ModelUtilities
attribute), 8

N

n_ODE (pvder.DER_components_single_phase.SolarPVDERSinglePhase
attribute), 5

n_steps (pvder.DER_utilities.PVDER_ModelUtilities
attribute), 10

O

ODE_model() (pvder.DER_components_single_phase.SolarPVDERSinglePhase
method), 5

ODE_model() (pvder.DER_components_three_phase.SolarPVDERThreePhase
method), 4

ODE_model() (pvder.dynamic_simulation.DynamicSimulation
method), 14

ODE_model_ode() (pvder.simulation_utilities.SimulationUtilities
method), 18

override_angle (pvder.simulation_events.SimulationEvents
attribute), 16

P

parameters (pvder.simulation_utilities.SimulationResults
attribute), 17

plot_DER_simulation()
(pvder.simulation_utilities.SimulationResults
method), 17

plot_multiple() (pvder.simulation_utilities.SimulationResults
method), 18

power_error_calc()
(pvder.DER_check_and_initialize.PVDER_SetupUtilities
method), 8

print_event() (pvder.DER_features.PVDER_SmartFeatures
method), 13

PRINT_INLINE (pvder.DER_utilities.PVDER_ModelUtilities
attribute), 8

print_LVRT_events()
(pvder.DER_features.PVDER_SmartFeatures
method), 12

print_reconnect_events()
(pvder.DER_features.PVDER_SmartFeatures
method), 13

print_VRT_events()
(pvder.DER_features.PVDER_SmartFeatures
method), 13

pvder.DER_check_and_initialize (module), 6

pvder.DER_components_single_phase (mod-
ule), 4

pvder.DER_components_three_phase (mod-
ule), 3

pvder.DER_features (module), 11

pvder.DER_utilities (module), 8

pvder.dynamic_simulation (module), 13

pvder.simulation_events (module), 15

pvder.simulation_utilities (module), 17

PVDER_ModelUtilities (class in
pvder.DER_utilities), 8

PVDER_SetupUtilities (class in
pvder.DER_check_and_initialize), 6

PVDER_SmartFeatures (class in
pvder.DER_features), 11

Q

Q_volt_VAR_absorb()
(pvder.DER_features.PVDER_SmartFeatures
method), 12

Q_volt_VAR_inject()
(pvder.DER_features.PVDER_SmartFeatures
method), 12

qlimit_calc() (pvder.DER_features.PVDER_SmartFeatures
method), 12

Qref_EXTERNAL (pvder.DER_utilities.PVDER_ModelUtilities
attribute), 8

R

ramp_del_t (pvder.DER_utilities.PVDER_ModelUtilities
attribute), 10

RAMP_ENABLE (pvder.DER_utilities.PVDER_ModelUtilities attribute), 8
 RAMP_FLAG (pvder.DER_utilities.PVDER_ModelUtilities attribute), 8
 ramp_list (pvder.DER_utilities.PVDER_ModelUtilities attribute), 10
 remove_grid_event () (pvder.simulation_events.SimulationEvents method), 16
 remove_load_event () (pvder.simulation_events.SimulationEvents method), 16
 remove_solar_event () (pvder.simulation_events.SimulationEvents method), 16
 reset_event_counters () (pvder.simulation_events.SimulationEvents method), 16
 reset_reference_counters () (pvder.DER_utilities.PVDER_ModelUtilities method), 10
 reset_stored_trajectories () (pvder.dynamic_simulation.DynamicSimulation method), 14
 RT_initialize () (pvder.DER_features.PVDER_SmartFeatures method), 12
 run_simulation () (pvder.dynamic_simulation.DynamicSimulation method), 14

S
 S_calc () (pvder.DER_components_single_phase.SolarPVDERSinglePhase method), 5
 S_calc () (pvder.DER_components_three_phase.SolarPVDERThreePhase method), 4
 S_G_calc () (pvder.DER_components_single_phase.SolarPVDERSinglePhase method), 5
 S_G_calc () (pvder.DER_components_three_phase.SolarPVDERThreePhase method), 4
 S_load1_calc () (pvder.DER_components_single_phase.SolarPVDERSinglePhase method), 5
 S_load1_calc () (pvder.DER_components_three_phase.SolarPVDERThreePhase method), 4
 S_PCC_calc () (pvder.DER_components_single_phase.SolarPVDERSinglePhase method), 5
 S_PCC_calc () (pvder.DER_components_three_phase.SolarPVDERThreePhase method), 4
 S_PCCph_calc () (pvder.DER_utilities.PVDER_ModelUtilities method), 8
 save_parameter_dictionary () (pvder.DER_utilities.PVDER_ModelUtilities method), 10
 save_plot () (pvder.simulation_utilities.SimulationResults method), 18
 SAVE_PLOT_JPEG (pvder.simulation_utilities.SimulationResults attribute), 17
 SAVE_PLOT_SVG (pvder.simulation_utilities.SimulationResults attribute), 17
 set_Vdc_ref () (pvder.DER_utilities.PVDER_ModelUtilities method), 10
 show_events () (pvder.simulation_events.SimulationEvents method), 16
 show_parameter_dictionaries () (pvder.DER_utilities.PVDER_ModelUtilities method), 10
 show_parameter_types () (pvder.DER_utilities.PVDER_ModelUtilities method), 10
 show_PV_DER_parameters () (pvder.DER_utilities.PVDER_ModelUtilities method), 10
 show_PV_DER_states () (pvder.DER_utilities.PVDER_ModelUtilities method), 10
 show_references () (pvder.DER_utilities.PVDER_ModelUtilities method), 10
 show_RT_flags () (pvder.DER_features.PVDER_SmartFeatures method), 13
 show_RT_settings () (pvder.DER_features.PVDER_SmartFeatures method), 13
 show_simulation_time () (pvder.dynamic_simulation.DynamicSimulation method), 14
 simulation_events_list (pvder.simulation_events.SimulationEvents attribute), 16
 SolarPVDERSinglePhase (class in pvder.simulation_events), 15
 SolarPVDERThreePhase (class in pvder.simulation_utilities), 17
 SolarPVDERSinglePhase (class in pvder.simulation_utilities), 18
 SolarPVDERThreePhase (class in pvder.simulation_events), 17
 SolarPVDERSinglePhase (class in pvder.DER_components_single_phase), 4
 SolarPVDERThreePhase (class in pvder.DER_components_three_phase), 3
 solver_list (pvder.simulation_utilities.SimulationUtilities attribute), 18
 solver_spec (pvder.DER_check_and_initialize.PVDER_SetupUtilities attribute), 8
 steady_state_calc () (pvder.DER_check_and_initialize.PVDER_SetupUtilities method), 8
 steadystate_solver

(pvder.DER_check_and_initialize.PVDER_SetupUtilities attribute), 8
 tInc (pvder.dynamic_simulation.DynamicSimulation attribute), 14
 steadystate_values (pvder.DER_check_and_initialize.PVDER_SetupUtilities attribute), 8
 tInc (pvder.dynamic_simulation.DynamicSimulation attribute), 14

T

t_calc() (pvder.dynamic_simulation.DynamicSimulation method), 14
 t_disconnect_low_limit (pvder.DER_features.PVDER_SmartFeatures attribute), 13
 t_reconnect_low_limit (pvder.DER_features.PVDER_SmartFeatures attribute), 13
 t_threshold_high_limit (pvder.DER_features.PVDER_SmartFeatures attribute), 13
 Tactual_default (pvder.simulation_events.SimulationEvents attribute), 15
 time_series_duty_cycle() (pvder.dynamic_simulation.DynamicSimulation method), 15
 time_series_inv_terminal_voltage() (pvder.dynamic_simulation.DynamicSimulation method), 15
 time_series_PCC_HV_side_voltage() (pvder.dynamic_simulation.DynamicSimulation method), 15
 time_series_PCC_LV_side_voltage() (pvder.dynamic_simulation.DynamicSimulation method), 15
 time_series_phase_angle() (pvder.dynamic_simulation.DynamicSimulation method), 15
 time_series_PLL() (pvder.dynamic_simulation.DynamicSimulation method), 15
 time_series_power_transfer() (pvder.dynamic_simulation.DynamicSimulation method), 15
 time_series_Ppv() (pvder.dynamic_simulation.DynamicSimulation method), 15
 time_series_RMS() (pvder.dynamic_simulation.DynamicSimulation method), 15
 time_series_S() (pvder.dynamic_simulation.DynamicSimulation method), 15
 time_series_standalone_grid() (pvder.dynamic_simulation.DynamicSimulation method), 15
 time_series_Zload1() (pvder.dynamic_simulation.DynamicSimulation method), 15

U

update_DER_config() (pvder.DER_check_and_initialize.PVDER_SetupUtilities method), 8
 update_DER_parameter() (pvder.DER_check_and_initialize.PVDER_SetupUtilities method), 8
 update_event_totals() (pvder.simulation_events.SimulationEvents method), 17
 update_events_spec() (pvder.simulation_events.SimulationEvents method), 17
 update_grid_measurements() (pvder.dynamic_simulation.DynamicSimulation method), 15
 update_inverter_frequency() (pvder.DER_components_single_phase.SolarPVDERSinglePhase method), 6
 update_inverter_frequency() (pvder.DER_components_three_phase.SolarPVDERThreePhase method), 4
 update_inverter_states() (pvder.DER_components_single_phase.SolarPVDERSinglePhase method), 6
 update_inverter_states() (pvder.DER_components_three_phase.SolarPVDERThreePhase method), 4
 update_iref() (pvder.DER_components_single_phase.SolarPVDERSinglePhase method), 6
 update_iref() (pvder.DER_components_three_phase.SolarPVDERThreePhase method), 4
 update_parameter_dict() (pvder.DER_utilities.PVDER_ModelUtilities method), 10
 update_power() (pvder.DER_components_single_phase.SolarPVDERSinglePhase method), 6
 update_power() (pvder.DER_components_three_phase.SolarPVDERThreePhase method), 4
 update_Ppv() (pvder.DER_utilities.PVDER_ModelUtilities method), 10
 update_Qref() (pvder.DER_utilities.PVDER_ModelUtilities method), 10
 update_ridethrough_flags() (pvder.DER_features.PVDER_SmartFeatures method), 13
 update_RMS() (pvder.DER_components_single_phase.SolarPVDERSinglePhase method), 6

update_RMS () (pvder.DER_components_three_phase.SolarPVDERThreePhase method), 4
 update_RT_config () (pvder.DER_features.PVDER_SmartFeatures attribute), 12
 update_RT_config_old () (pvder.DER_features.PVDER_SmartFeatures attribute), 12
 update_RT_config_old () (pvder.DER_features.PVDER_SmartFeatures method), 12
 update_Vdc_ref () (pvder.DER_utilities.PVDER_ModelUtilities method), 12
 update_Vdc_ref () (pvder.DER_utilities.PVDER_ModelUtilities method), 10
 update_voltages () (pvder.DER_components_single_phase.SolarPVDERSinglePhase method), 6
 update_voltages () (pvder.DER_components_three_phase.SolarPVDERThreePhase method), 17
 update_voltages () (pvder.DER_components_three_phase.SolarPVDERThreePhase method), 4
 update_Zload1 () (pvder.DER_utilities.PVDER_ModelUtilities method), 5
 update_Zload1 () (pvder.DER_utilities.PVDER_ModelUtilities method), 10
 use_frequency_estimate (pvder.DER_utilities.PVDER_ModelUtilities attribute), 10

V

V_threshold_high_limit (pvder.DER_features.PVDER_SmartFeatures attribute), 12
 va_calc () (pvder.DER_utilities.PVDER_ModelUtilities method), 10
 Vabrms_calc () (pvder.DER_components_single_phase.SolarPVDERSinglePhase method), 5
 Vabrms_calc () (pvder.DER_components_three_phase.SolarPVDERThreePhase method), 4
 validate_model () (pvder.DER_utilities.PVDER_ModelUtilities method), 11
 vb_calc () (pvder.DER_utilities.PVDER_ModelUtilities method), 11
 vc_calc () (pvder.DER_utilities.PVDER_ModelUtilities method), 11
 Vdc_actual (pvder.DER_utilities.PVDER_ModelUtilities attribute), 8
 Vdc_ref_counter (pvder.DER_utilities.PVDER_ModelUtilities attribute), 8
 Vdc_ref_list (pvder.DER_utilities.PVDER_ModelUtilities attribute), 8
 Vdc_ref_ramp () (pvder.DER_utilities.PVDER_ModelUtilities method), 8
 Vdc_ref_total (pvder.DER_utilities.PVDER_ModelUtilities attribute), 9
 VERBOSE (pvder.DER_utilities.PVDER_ModelUtilities attribute), 8
 Volt_VAR_absorb_range () (pvder.DER_features.PVDER_SmartFeatures method), 12

voltage_ramp () (pvder.simulation_events.SimulationEvents method), 17
 Vrms_calc () (pvder.DER_components_single_phase.SolarPVDERSinglePhase method), 5
 Vrms_calc () (pvder.DER_components_three_phase.SolarPVDERThreePhase method), 4
 Vrms_min_calc () (pvder.DER_components_three_phase.SolarPVDERThreePhase method), 4
 VRT_initialize () (pvder.DER_features.PVDER_SmartFeatures method), 12
 vta_calc () (pvder.DER_utilities.PVDER_ModelUtilities method), 11
 Vtabrms_calc () (pvder.DER_components_three_phase.SolarPVDERThreePhase method), 4
 vtb_calc () (pvder.DER_utilities.PVDER_ModelUtilities method), 11
 vtc_calc () (pvder.DER_utilities.PVDER_ModelUtilities method), 11
 Vtrms_calc () (pvder.DER_components_single_phase.SolarPVDERSinglePhase method), 5
 Vtrms_calc () (pvder.DER_components_three_phase.SolarPVDERThreePhase method), 4

W

we_calc () (pvder.DER_utilities.PVDER_ModelUtilities method), 11
 wgrid_calc () (pvder.DER_utilities.PVDER_ModelUtilities method), 11
 wgrid_estimate () (pvder.DER_utilities.PVDER_ModelUtilities method), 11
 wgrid_estimate_calc () (pvder.DER_utilities.PVDER_ModelUtilities method), 11

Y

y0 (pvder.DER_components_single_phase.SolarPVDERSinglePhase attribute), 6
 y0 (pvder.DER_components_three_phase.SolarPVDERThreePhase attribute), 4
 y0 (pvder.dynamic_simulation.DynamicSimulation attribute), 15

Z

`Zload1_actual_default`
(*pvder.simulation_events.SimulationEvents*
attribute), [16](#)