An online simulator of PV systems

Input and output data

(Version 1.0)

November 2014

INDEX

1. Introduction

This document describes some basic features of the source code of SISIFO and the list of input and output data.

The released source code, which has been written in the PHP programming language, includes the functions with all models and algorithms. The explanation of the models, algorithms and calculation steps are included as comments inside the code.

This is the first version of SISIFO and the effort has been made in the implementation of the radiation and power models but not in optimising the structure, data or algorithms, which will be a concern for future versions.

SISIFO is free software: you can redistribute it and/or modify it under the terms of the GNU Affero General Public License version 3 (AGPLv3.0).

2. Input data

To execute SISIFO you must call the function "SISIFO.php", which reads the input data written in the "InputParameters.php" file.

This input data, as well internal calculations derived from this, is organised in the following eight categories, which are arrays indexed by key:

- **SITE** (geographical data)
- **METEO** (meteorological input data)
- **PVMOD** (characteristics of the PV modules)
- **PVGEN** (characteristics of the PV generators, including those of the static and tracking structures)
- **BOS** (Balance-Of-System components: inverter, transformers, wiring and gensets).
- **OPTIONS** (type of applications, analysis and models)
- **TIME** (simulation step and local time)
- **ECO** (economic and financial data inputs)

Each one of these arrays has different fields, which may contain variables or nested arrays, which may be numeric or indexed by key, and so on.

For example, the array SITE contains the fields: Latitude, lat, Altitude, Longitude, StandardLongitude, Location and Project, and it has the following declaration:

```
$SITE= array(     'Latitude'  => $Latitude,
                  'lat'       => $lat,
                  'Altitude'  => $Altitude,
                  'Longitude' => $Longitude,
                  'StandardLongitude' => $StandardLongitude,
                  'Location'  => $Location,
                  'Project'    => $Project);
```

In the previous example, to access to a particular field, write the array name, followed by brackets and the field name inside simple quotes:

$SITE['Latitude']

Other arrays may contain fields that are themselves arrays. For example, BOS contains three arrays called INVERTER, TRANSFORMER and WIRING, which, themselves, have other arrays inside.

To display the fields of the nested array, write the name of the main array followed by brackets, simple quotes and the field name of the nested array. For example:

$BOS['INVERTER']

To access a particular field of the previous array, write brackets and simple quotes followed by the field name. For example, to access the "Efficiency" of the INVERTER:

$BOS['INVERTER']['Efficiency']

3. Output data

Results of an individual yearly simulation are contained in an array called RESULTS, which includes the following four arrays: MATRICES, DAILY, MONTHLY, YEARLY.

The array MATRICES contains the instantaneous values of the simulated variables, which are arrays contained in arrays (two-dimensional matrices) where the first dimension is the day (d) and the second dimension is the time (h). Hence, each matrix has dxh elements, for example, 365x24=8760 values in the case of hourly simulations. This array includes three nested arrays with the following names (contents): HI (Horizontal Irradiances), ISI (Inclined Surface Irradiances), and POWER (Powers in the PV system).

The array DAILY contains several nested arrays (1x365 size) with daily parameters, resulting of the integration of the previous matrices.

The array MONTHLY contains several nested arrays (1x12 size) with monthly parameters, resulting of the integration of the previous daily parameters.

The array YEARLY contains single variables (yearly parameters), resulting of the integration of the previous monthly parameters.

Next sections indicate the names and definitions of the available variables. It is worth mentioning that all the simulated variables, more than one hundred, have not been included in the array $RESULTS['MATRICES'] in order to avoid possible memory overloads when the simulation is performed with small simulation steps. However, it is possible to return or display any intermediate calculated variable or matrix, which is a local variable of a given function, by programming some minor modifications in the source code.

Finally, the array ECONOMICS contains single variables and arrays with the calculated economic parameters.

3-1 Meteorological variables

3-1-1 Radiation on the horizontal surface

The components of the solar irradiance on the horizontal surface are included in the array $RESULTS['MATRICES']['HI'], which are displayed in Table 1. For example, to call the global horizontal irradiance matrix write:

$RESULTS['MATRICES']['HI']['G0']

Table 1. Horizontal irradiances.

Variable	Unit	Definition
G0	$W \cdot m^{-2}$	Global
B0	"	Beam
D0	"	Diffuse

3-1-2 Radiation on the inclined surface

The components of the solar irradiance on the inclined surface (plane of the array) are included in the array $RESULTS['MATRICES']['ISI'], which are displayed in Table 2.

Table 2. Irradiances on the inclined surface.

Variable	Unit	Definition
G	$W \cdot m^{-2}$	Global
B	"	Beam
D	"	Diffuse
R	"	Reflected
Gef	"	Global effective (includes dust and incidence effects)
Bef	"	Beam effective
Def	"	Diffuse effective
Ref	"	Reflected effective
Gefsa	"	Global effective plus adjacent shading
Befsa	"	Beam effective plus adjacent shading
Defsa	"	Diffuse effective plus adjacent shading
Gefsayp	"	Global effective plus adjacent and back shading
Befsayp	"	Beam effective plus adjacent and back shading
Defsayp	"	Diffuse effective plus adjacent and back shading
Gefsaypce	"	Global effective plus adjacent and back shading, and spectral correction
Befsaypce	"	Beam effective plus adjacent and back shading, and spectral correction
Defsaypce	"	Diffuse effective plus adjacent and back shading, and spectral correction
Refce	"	Reflected effective and spectral correction

3-1-3 Daily, monthly and yearly irradiations

Daily, montly and yearly irradiations are indicated, respectively, with the suffixes "d", "m" and "a" after the name of the variables displayed in Table 1 and Table 2. And they are contained, respectively, in DAILY, MONTHLY, and YEARLY arrays.

For example, as G0 is the global horizontal irradiance:

G0d is the daily horizontal irradiation, $Wh \cdot m^{-2}$ (365 values).

G0m is the monthly horizontal irradiation, $Wh \cdot m^{-2}$ (12 values).

G0a is the yearly horizontal irradiation, $Wh \cdot m^{-2}$ (1 value).

The previous parameters are referenced, respectively, as:

$RESULTS['DAILY']['G0d']

$RESULTS['MONTHLY']['G0m']

$RESULTS['YEARLY']['G0a']

3-2 PV system

3-2-1 Powers

The power calculations in the conversion chain are included in the array $RESULTS['MATRICES']['POWER'], which are displayed in Table 3.

Table 3. PV system powers

Variable	Unit	Definition
PDCSP	kW/kWp	Nominal DC power
PDCPP	"	Less mismatch losses, power below the nominal one, and other effects (all these losses are included in the PRVPN parameter of PVGEN)
PDCPE	"	Less seasonal losses (a-Si)
PDCPT	"	Less temperature losses
PDCBI	"	Including the correction of PV efficiency at low irradiances
PDCPC	"	Less the losses in DC wiring
PDC	"	DC power at the input of the inverter after taking into account the saturation of the inverter and the irradiance threshold
PACAC	"	AC power at the output of the inverter
PAC	"	AC power at the input of the LV/MV transformer after discounting LV wiring losses between the inverter and the LV/MV transformer.
PACMTAC	"	AC power at the output of the LV/MV transformer
PACMT	"	AC power at the input of the MV/HV transformer after discounting MV wiring losses between LV/MV and MV/HV transformers

3-2-2 Electric energies

Daily, monthly and yearly energies are obtained by the integration of the all powers indicated in Table 3.

The names of these energies are created using the following convention. First, the initial P (of power) is replaced by E (of energy). Second, one of the suffixes "d", "m" or " is added after the name to indicate, respectively, the daily, monthly or yearly energy.

For example, as PAC is the power at the input of the LV/MV transformer:

EACd is the daily AC energy at the input of the LV/MV transformer, in kWh/kWp (365 values).

EACm is the daily AC energy at the input of the LV/MV transformer, in kWh/kWp (12 values)

EACa is the daily AC energy at the input of the LV/MV transformer, in kWh/kWp (1 value).

The previous parameters are called, respectively, as:

$RESULTS['DAILY']['EACd']

$RESULTS['MONTHLY']['EACm']

$RESULTS['YEARLY']['EACa']

3-2-3 Performance ratios (PR)

Ideal performance ratios are calculated for each month and for the complete year (see Table 4), which are contained, respectively, in MONTHLY and YEARLY arrays.

Table 4. Ideal performance ratios

Variable	Unit	Definition
PRDCm	Per unit	Array with the monthly performance ratios in DC
PRACm	"	Array with the monthly performance ratios in LV
PRACMTm	"	Array with the monthly performance ratios in MV
PRDCa	"	Yearly performance ratio in DC
PRACa	"	Yearly performance ratio in LV
PRACMTa	"	Yearly performance ratio in MV

Besides, yearly experimental PR are also calculated, which are displayed in Table 5. Experimental PR does not include energy losses caused by the spectral response of the PV modules, incidence angle and soiling. Hence, experimental PR are higher than ideal ones.

Table 5. Experimental performance ratios

Variable	Unit	Definition
PRexpDCa	Per unit	Yearly performance ratio in DC
PRexpACa	"	Yearly performance ratio in LV
PRexpACMTa	"	Yearly performance ratio in MV

3-2-4 Efficiencies and individual losses

Yearly efficiencies and individual losses are displayed in Table 6.

Table 6. Efficiencies and individual losses

Variable	Unit	Definition
PER_INCa	Per unit	Incidence (reflection, transmission and dust)
PER_SOMa	Per unit	Shading
PER_ESPa	Per unit	Spectrum
PER_POTa	%	PV real power versus nominal
PER_ESTa	%	Seasonal (a-Si)
PER_TEMa	%	Temperature
PER_BIa	%	Low irradiances
PER_CDCa	%	DC wiring
PER_UMBa	%	Minimum irradiance and inverter saturation
etaia	%	Inverter energy efficiency
PER_INVa	%	Inverter losses
PER_CACa	%	AC wiring
Etamta	%	LV/MV conversion efficiency (transformer)
PER_MTa	%	LV/MV energy conversion losses

3-2-5 Yields and performance losses

Yearly efficiencies and individual losses are displayed in Table 7.

Table 7. Efficiencies and individual losses

Variable	Unit	Definition
Yr	kWh/kWp	Reference yield
Ya	kWh/kWp	Array yield
Yf	kWh/kWp	Final yield
LCa	%	Capture losses relative to Yr
LSa	%	System losses relative to Yr

3-3 Economic parameters

Economic variables are contained in the array called ECONOMICS, which is composed of simple variables and arrays that are displayed in Table 8.

To access to simple variables such as LCOEr, you have to enter $ECONOMICS['LCOEr']. And to access in an array, such as energy production per year over the life of the project (E_output), you have to enter $ECONOMICS['E_output'], obtaining for a project duration of 20 years, 20 values.

Table 8. Economic parameters

Variable	Unit	Definition
LifetimeFIT	Years	Project lifetime for feed-in tariff term
Equity	€	Part of the total investment costs covered by shareholders' equity.
LoanAmount	€	Part of the total investment costs covered by a bank loan.
E_output	kWh	Electricity production for every year of analysis
FIT_updated	c€/kWh	Updated feed-in tariff for every year of analysis
I_energy	€	Annual incomes, related to the value of produced energy according to FIT

CfOM_updated	€	Annual fixed operating expenses, updated with inflation rate and extra increases
CvOM_updated	€	Annual variable operating expenses, updated with inflation rate and extra increases
Ctransm_updated	€	Annual electricity transmission costs
COM	€	Total annual operating expenses, including energy transmission charge
Unpaid	€	Remaining unpaid debt for each year
Pay_Int	€	Yearly debt interests payment
Pay_Cap	€	Yearly capital payment
Pay_total	€	Total debt payment
I_taxable	€	Taxable income (benefits after interests payment)
Tax	€	Annual income taxes
Exp_wo_tax	€	Total periodical expenses with financing & without taxes
Exp_w_tax	€	Total periodical expenses with financing & with taxes
CF_wo_tax	€	Annual cashflow after debt & without taxes
CF_w_tax	€	Annual cashflow after debt & after taxes
CF_Acc	€	Accumulated investment cashflow
NPV_inc	€	Incomes nominal Net Present Value NPV
NPV_exp_wo	€	Expenses with financing & without tax nominal NPV, including initial investment of equity
NPV_exp	€	Expenses with financing & with tax nominal NPV, including initial investment of equity
NPVn_elec	kWh	Energy production nominal NPV
NPVr_elec	kWh	Energy production real NPV
LCOEn_wo	c€/kWh	With financing and without tax
LCOEr_wo	c€/kWh	With financing and without tax
LCOEn	c€/kWh	With financing and with tax
LCOEr	c€/kWh	With financing and with tax