PV System Design with PVsyst

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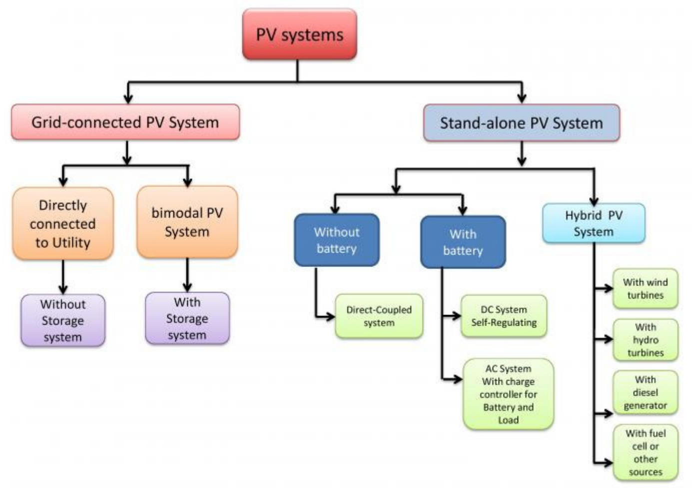
"Training on Renewable Energy Policy Tools
and Energy Technologies Best Practices"

CES Solar Cells Testing Center (CSSC)
King Mongkut's University of Technology Thonburi (KMUTT)
November 23, 2018

TOPICS

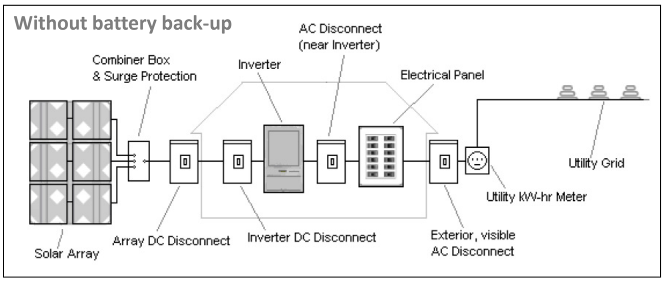
- ❑ PV System Applications and Design Criteria
- ❑ Software for PV System Design
- ❑ Concepts of PV System Design with PVsyst
- ❑ Exercises with PVsyst

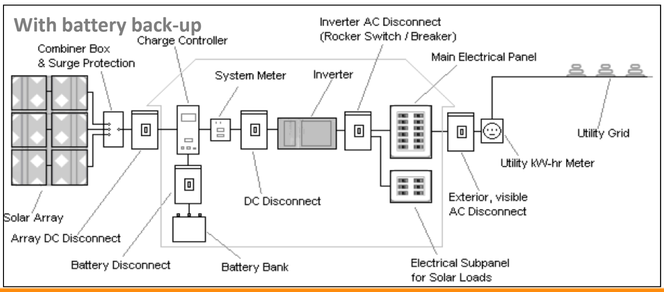
PV System Applications and Design Criteria



PV System Applications and Design Criteria

Configuration of a grid-connected AC PV system

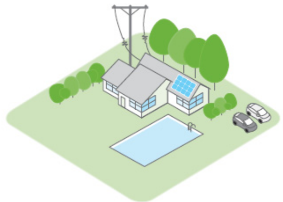




Solar Electric System Design, Operation and Installation

PV System Applications and Design Criteria

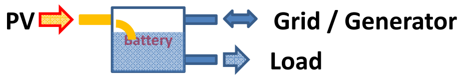
Grid-connected PV System with Battery Back-up

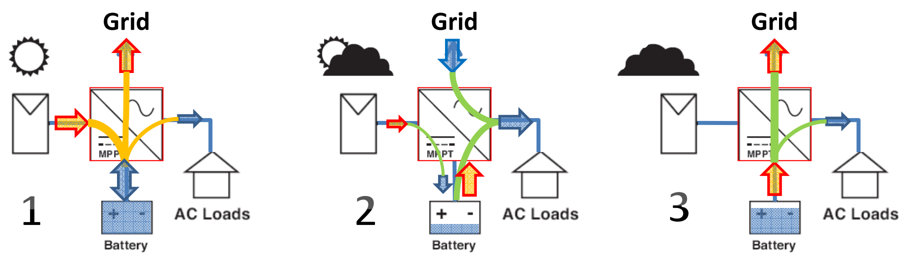


Residential grid-interactive solar with battery backup

Case	Solar	Load	Bat.	Grid
1	High	Low	Full	Export
2	Low	High	Discharge	Import
3*	No	Low	Discharge	Export

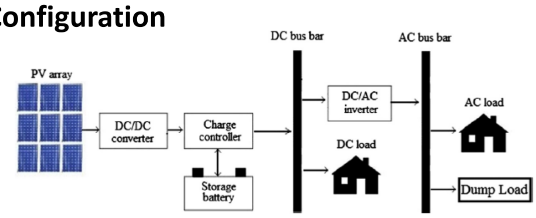
*Case 3 is when export energy to the grid during network peak (20:00 – 22:00)

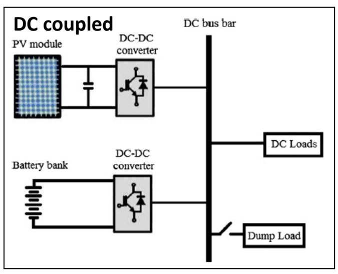


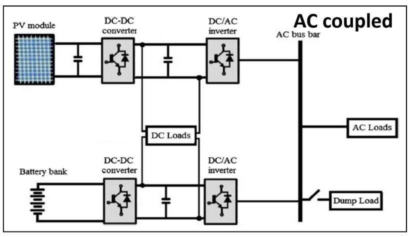


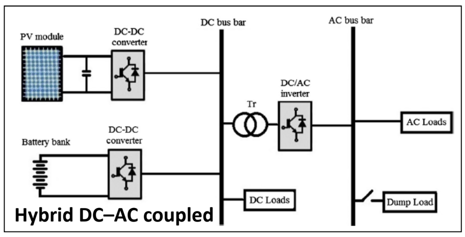
PV System Applications and Design Criteria

Standalone (off-grid) PV system Configuration



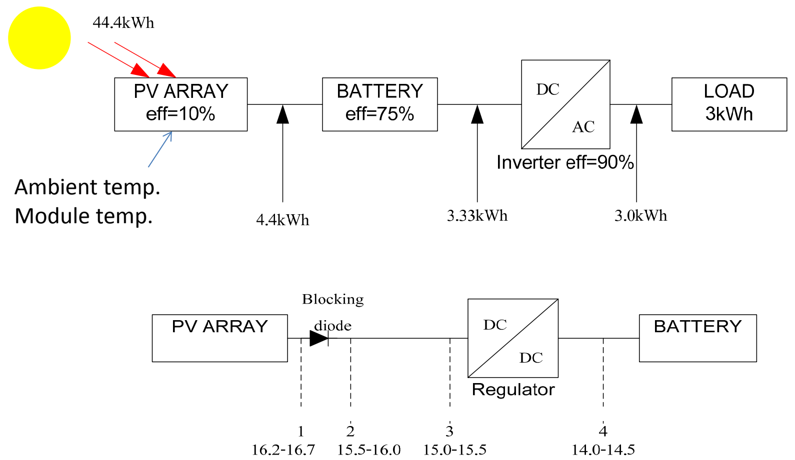






Tamer Khatib et. al., A review on sizing methodologies of photovoltaic array and storage battery in a standalone photovoltaic system

PV System Applications and Design Criteria

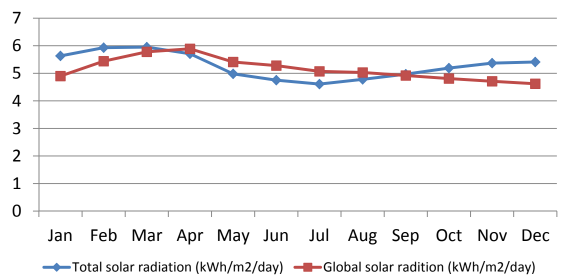


PV System Applications and Design Criteria

Solar Irradiation

PV plane of 14 degrees incline angle which is the optimum tilt angle in Bangkok.

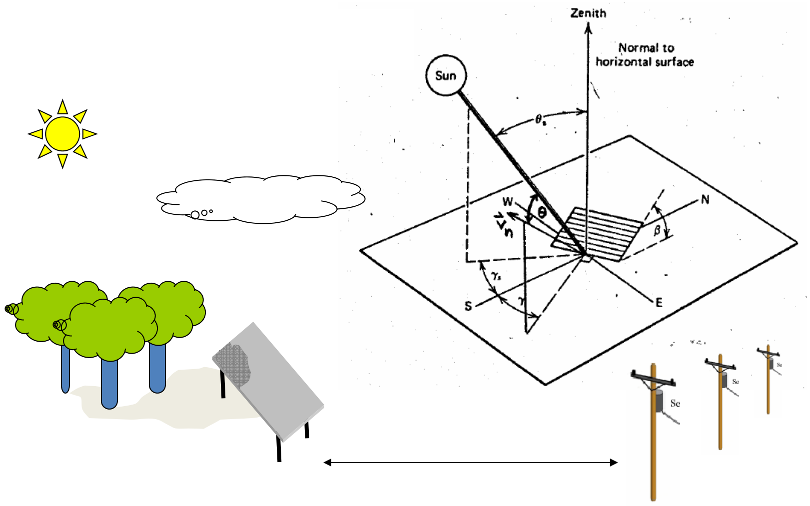
Daily solar radiation	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Total (kWh/m²/day)	5.63	5.93	5.95	5.71	4.98	4.75	4.61	4.78	4.97	5.19	5.37	5.41
Global (kWh/m²/day)	4.9	5.44	5.78	5.89	5.41	5.28	5.07	5.03	4.92	4.81	4.71	4.62



Data from Department of Alternative Energy Development and Efficiency (DEDE)

PV System Applications and Design Criteria

Site and Building factors



PV System Applications and Design Criteria

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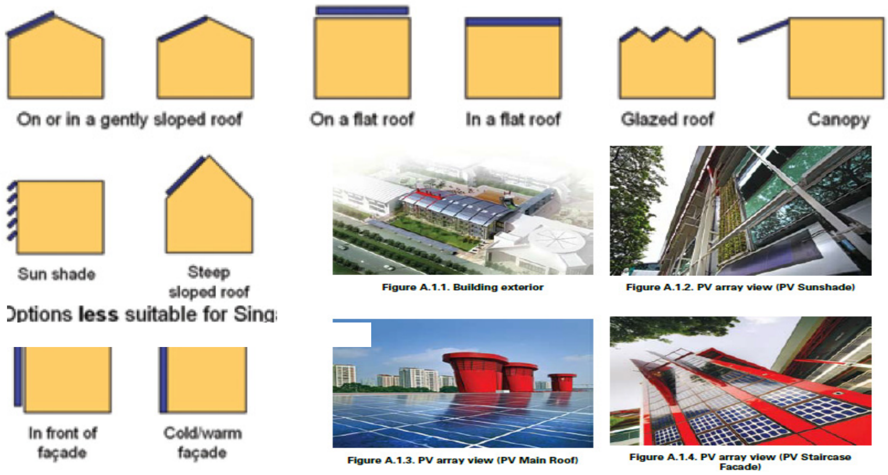
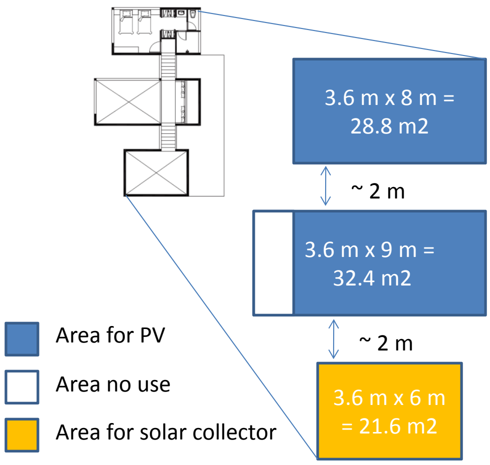


Handbook for Solar Photovoltaic (PV) Systems, The Building and Construction Authority (BCA), Singapore

PV System Applications and Design Criteria

Available Area for PV Installation

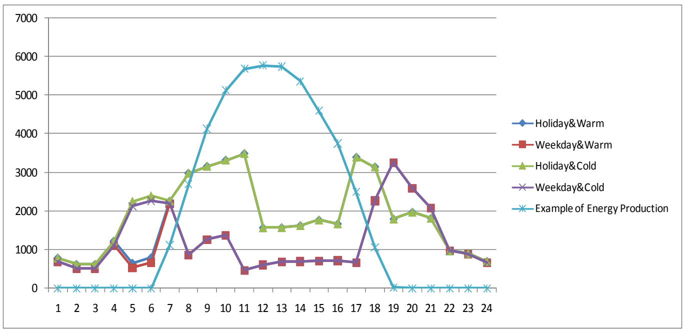


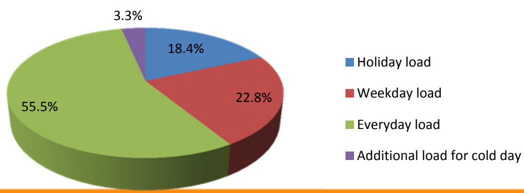
Roof No.1	28.8 m2
Roof No.2	32.4 m2
Roof No.3	21.6 m2
Total	**82.8 m2**
Area for others	25.2 m2
Area for PV	**57.6 m2**

PV System Applications and Design Criteria

Load Consumption

Hourly Power production and consumption (Watts)





PV System Applications and Design Criteria

Load Consumption

System	Appliences	Q'ty	Power (W)	Operating hours/day	Energy use (kWh / day)	Day use (days/year)	Energy use (kWh / year)
House Functioning	Refrigerator	1	60	24.00	1.44	365	525.60
	Freezer	1	120	24.00	2.88	52	150.17
	Washing Machine	1	2000	2.00	4.00	52	208.57
	Clothes dryer	1	2000	1.00	2.00	52	104.29
	Dishwasher	1	600	1.00	0.60	209	125.14
	Television	1	65	7.00	0.46	365	166.08
	Computer	1	170	4.00	0.68	261	177.29
	DVD Player	1	20	3.00	0.06	261	15.64
	Loudspeaker	1	30	3.00	0.09	261	23.46
	Oven	1	2500	1.00	2.50	104	260.71
	Stove (cooking)	1	1400	2.00	2.80	365	1022.00
Lighting System	Light bulbs	8	20	8.00	1.28	365	467.20
Air Handling System	*Air conditioner	2	2000	8.00	32.00	150	4800.00
	Ventilation Fan	3	30	8.00	0.72	180	129.60
Plumbing System	Electric pump	1	125	2.00	0.25	365	91.25
Monitoring System	Display unit	1	50	4.00	0.20	365	73.00
	Power&Energy meters	20	1	24.00	0.48	365	175.20
	Measuring Data Center	1	10	24.00	0.24	365	87.60
Others	Electric Fan	4	50	8.00	1.60	365	584.00
	Computer Notebook	1	70	8.00	0.56	365	204.40
				Total	**25.73**	**365**	**9391.2**

*For stand alone PV system, load is 3694.4 kWh/year if 2 air conditioners are not operated.

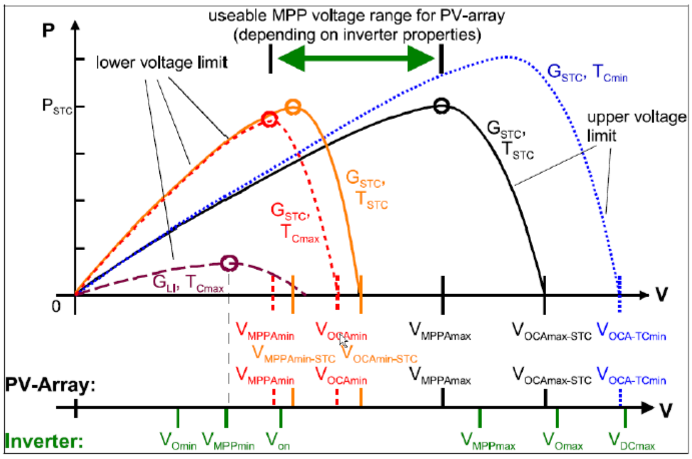
PV System Applications and Design Criteria

Criteria for components selection

Items	PV modules	Inverters	Batteries
Capacity	Consider load, size and inverter (should be >180 W)	~ 5kW , 50Hz, 230 V	For 3 days off-grid load
Limited capacity	PV array rated <= 1.5 inverter rated power	<= 5kW with >=2 MPPT or 1 MPPT & charge controllers	Depend on voltage , total size, and cost
Voltage	System voltage 1000V	PV string voltage	2V x 6, 12, 24
Efficiency	>=14 %	> 90%	> 70%
Warranty	>= 20 years	>= 5 years	>= 5 years
Life time	>= 25 years	>= 10 years	>= 10 years
Availability	Local agent or manufacturer	Local agent or manufacturer	Local agent or manufacturer
Cost	Reasonable	Reasonable	Reasonable
Size	Consider roof area and maximum installed power	Depend on capacity	Depend on capacity
Standard	IEC61215	IEC61727-2004 and IEC 62116	Safety standard TISI, IEC, UL
Reliability	High	High	High

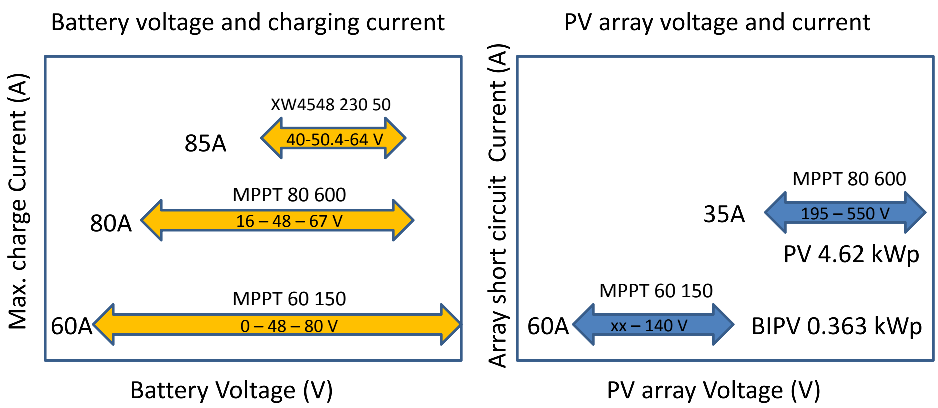
PV System Applications and Design Criteria

System Sizing and Configuration: Voltage and Current Limit



PV System Applications and Design Criteria

System Sizing and Configuration: Voltage and Current Limit



PV System Applications and Design Criteria

Criteria Parameters for PV System Design and Evaluation

Technical parameters (Off-grid)*
- Loss of power supply probability (LOSP)
- Loss of load probability (LOLP)
- Loss of load expected (LOLE)
- Equivalent loss factor (ELF)
- Total energy loss (TEL)
- State of charge (SOC)
- Level of autonomy (LA)

Economic parameters*
- Net present value (NPV)
- Annualized cost of a system (ACS)
- Total life cycle cost (TLCC)
- Capital recovery factor (CRF)
- Generation cost of energy (GCOE)
- Levelized cost of energy (LCOE)

Technical parameters (Grid)
- Reference Incident Energy in coll. Plane or Reference yield (Yr)
- Ya : Normalized Array Production or Array yield (Ya)
- Yf : Normalized System Production or System yield (Yf)
- PR : Performance Ratio (PR = Yf / Yr)

* Tamer Khatib et. al., A review on sizing methodologies of photovoltaic array and storage battery in a standalone photovoltaic system, *Energy Conversion and Management*, 2016

PV System Applications and Design Criteria

Limitation of different sizing methods

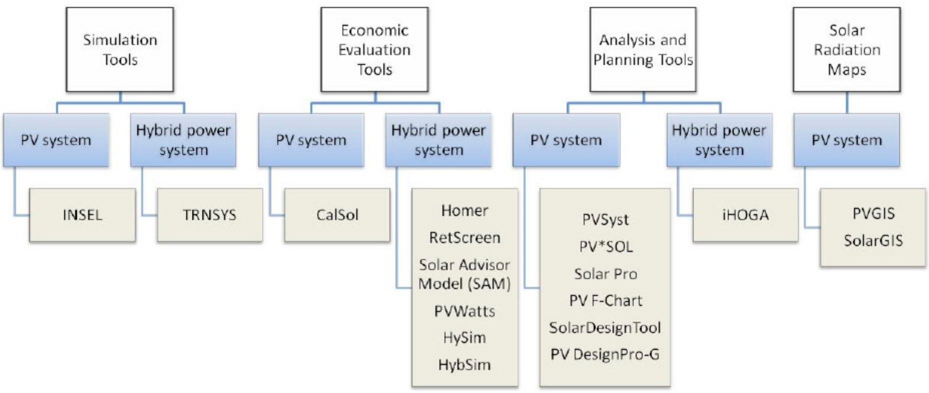
Sizing method	Input data*			Limitation
	H	D	M	
Intuitive (simplified) methods		•	•	Simple calculations used based on daily or monthly meteorological data may lead to over/under sizing of system design, low reliability and increase system capital, and maintenance and operation costs
Numerical methods	•	•	•	Suboptimal solutions are reached as computation involves linear changes of the decision variables
Analytical methods	•	•	•	Less flexible in designing a standalone PV system as performance is estimated by the computational models
Software tools	•	•	•	Unable to improve system components and limited ability to change the component specifications
AI methods	•	•	•	Complexity in designing system components
Hybrid methods	•	•	•	Complexity in designing system components which are based on complex algorithm functions

Remark: *Input data are the Hourly (H), Daily (D) and Monthly (M) average meteorological data.

Software for PV System Design

Software for PV System Design

Classification of PV system design tools based on application



Samer Alsadi and Tamer Khatib, Photovoltaic Power Systems Optimization Research Status: A Review of Criteria, Constrains, Models, Techniques, and Software Tools, Appl. Sci. 2018, 8, 1761; doi:10.3390

Software for PV System Design

Software	Developed by	Type of Analysis	Advantages	Disadvantages	Availability
SAM	National Renewable Energy Laboratory (NREL), USA. 2007	Performance analysis; Economic analysis	user friendly; easy to understand; graphical representation of results; Manually add custom modules and inverters	3D shade modeling is not supported; No available weather data for other locations of the world	Free
PVsyst	**Institute of Environmental Sciences (ISE), University of Geneva, Switzerland**	**Performance analysis; Financial estimation used for both grid-connected, stand-alone, pumping and DC-grid PV systems,**	**Extensive meteorological and PV systems components databases; Has ability to identify the weaknesses of the system design through Loss Diagram; Results include several dozens of simulation variables**	**Program screen cannot be maximized to enable user to see all parameters if using a small monitor; Inability to handle shadow analysis; No single line diagram**	**priced, 30-day trial version is free**
HOMER	National Renewable Energy Laboratory (NREL), USA	Optimization and Sensitivity analysis; Technical analysis; Financial analysis	Determines the possible combinations of a list of different technologies and its size; Very detailed results for analysis and evaluation; Has optimization algorithms used for feasibility and economic analysis	Inability to guest missing values or size; Sophisticated and time consuming; Detailed input data is needed	priced, 21-day free trial is available
PV*SOL	Valentine Energy Software, Germany	Shading analysis and 3D visualization; Performance analysis; Economic analysis	Vast meteorological database with over 8000 climatic location worldwide; Strong module and inverter database with over 13000 modules and 3100 inverters; Manually add custom modules and inverters	Sensitivity analysis is not supported; Complexity in building and site modeling; Error in the presentation of circuit diagram; Advanced scientific calculation is not supported	priced, 30-day trial version is free
RETScreen	Natural Resources Canada	Benchmark analysis; Feasibility analysis; Performance analysis; Portfolio analysis	Strong meteorological and product database; Contains extensive integrated training material; High strength in financial analysis	Inability to save, print and export files when using free view mode version; Data sharing problem; No option for time series data files Import; Does not support advanced calculations.	priced, Viewer mode is available free-of-charge

Najibhamisu Umar et. al., Comparison of different PV power simulation softwares: case study on performance analysis of 1 MW grid-connected PV solar power plant

Software for PV System Design

Software	Developed by	Type of Analysis	Advantages	Disadvantages	Availability
Solarius PV	ACCA software, Italy	Technical analysis; Economic analysis; Shading analysis	Extensive meteorological database; Numerical and graphical results can be easily exported; Has photographic simulation feature	Less user-friendly as compared to other softwares Advanced feasibility analysis is not supported; Internet connection is required for installation	priced, 30-day free trial version is available
HelioScope	Folsom Lab, San Francisco, USA	Technical analysis; shading analysis	User-friendly; Is a web-based tool, so there is no software to download; Provides a detailed wiring diagram; Has 3D model design	Does not support financial analysis; Does not support feasibility analysis; Does not support advance scientific calculation	30-day trial version is available
Solar Pro	Laplace Systems Company, Japan	Technical analysis; shading analysis; Economic analysis; Performance modeling	Strong meteorological database; Advanced 3D shading analyses; Provides system layouts; Provides detailed and customized reports which can be exported	Sophisticated software as compared to other softwares; Advanced feasibility study is not supported	Priced, 30-day trial is available
SOLARGIS	Solargis, Slovakia. 2010	Technical analysis; Planning and optimization	User-friendly; is a web-based tool, so there is no software to download; Provides a detailed output with graphs and tables	Not suitable for financial analysis; Less technical parameters; Feasibility analysis is not supported; Internet is needed to run the simulation.	30-day trial version is available

Najibhamisu Umar et. al., Comparison of different PV power simulation softwares: case study on performance analysis of 1 MW grid-connected PV solar power plant

Software for PV System Design

Table 1: Basic data of the systems investigated

Sys.	Location	Rated power	Azi-muth	Tilt	Start-Up
A	Munich	1,1 kWp	190°	30°/ 45°	1996
B	70 km south of Munich	1,1 kWp	160°	60°	24.06. 1996
C	20 km east of Munich	1,1 kWp	180°	60°	19.12. 1995

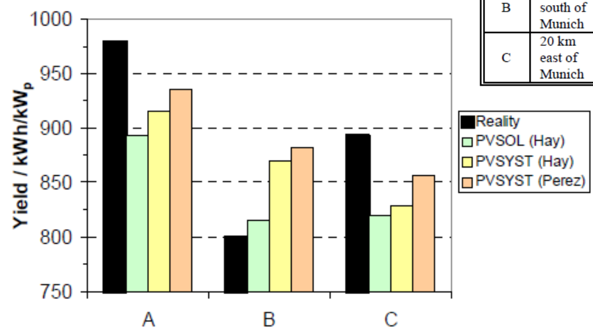
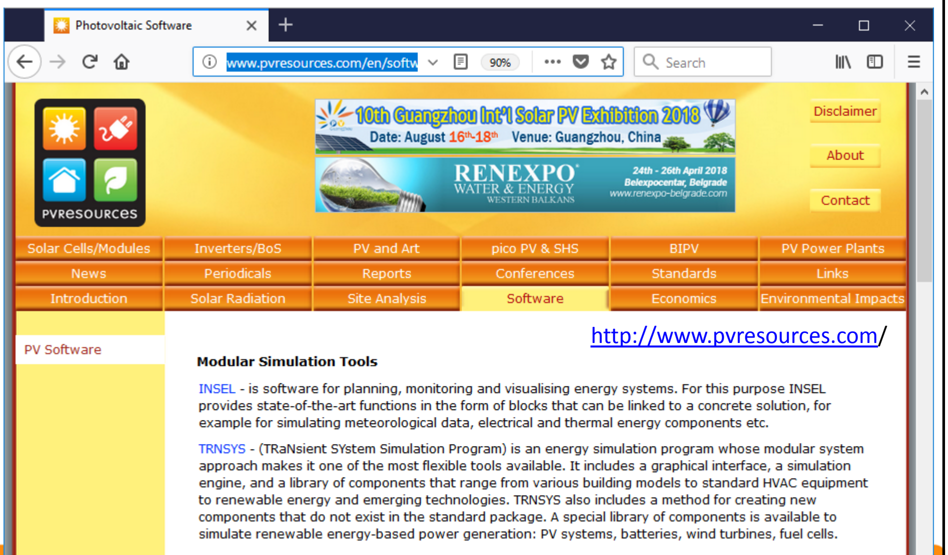


Figure 3: Comparison of real and simulated data

Gerd Becker et. al., Energy Yields of PV Systems - Comparison of Simulation and Reality

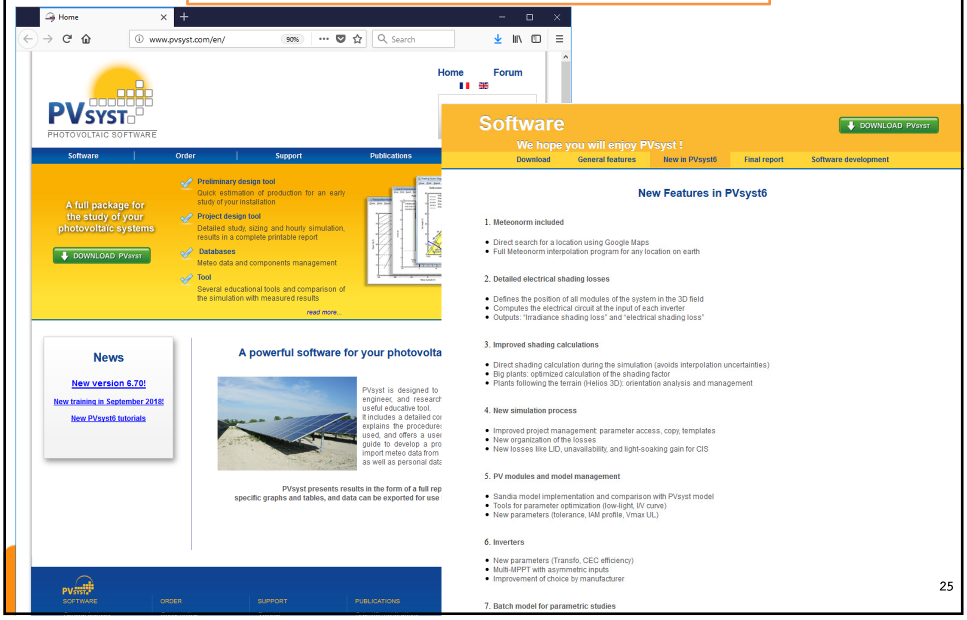
Software for PV System Design



http://www.pvresources.com/

Software for PV System Design

http://www.pvsyst.com/en/



Software for PV System Design

PVsyst: Photovoltaic Systems Software

Advantage

- Large database: PV component, meteorological sites
- Many systems: Grid-connected, Stand alone, Pumping, DC grid
- Parameters allowing fine effects analysis, including thermal behavior, wiring and mismatch losses, real module quality loss, incidence angle losses
- A 3-D CAO tool for "near shading“, animation
- economic evaluation performed using real component prices, additional costs and investment conditions, in any currency

Concepts of PV System Design with PVsyst

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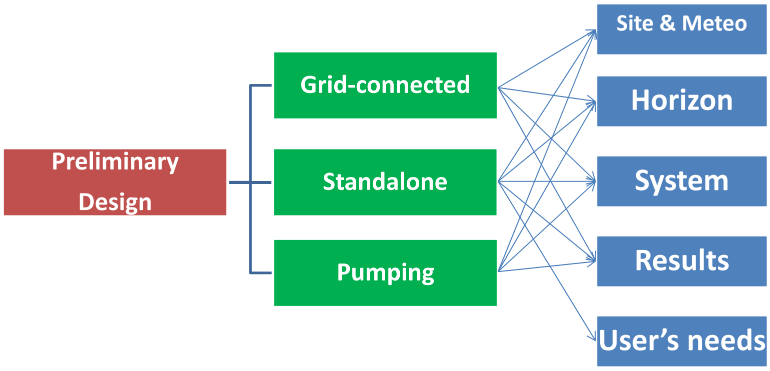

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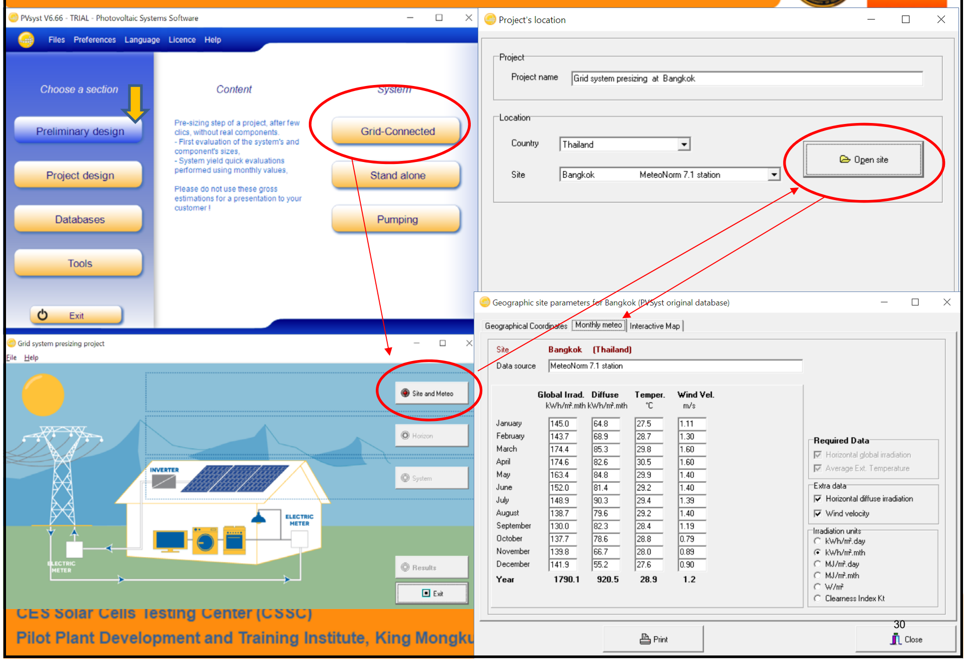

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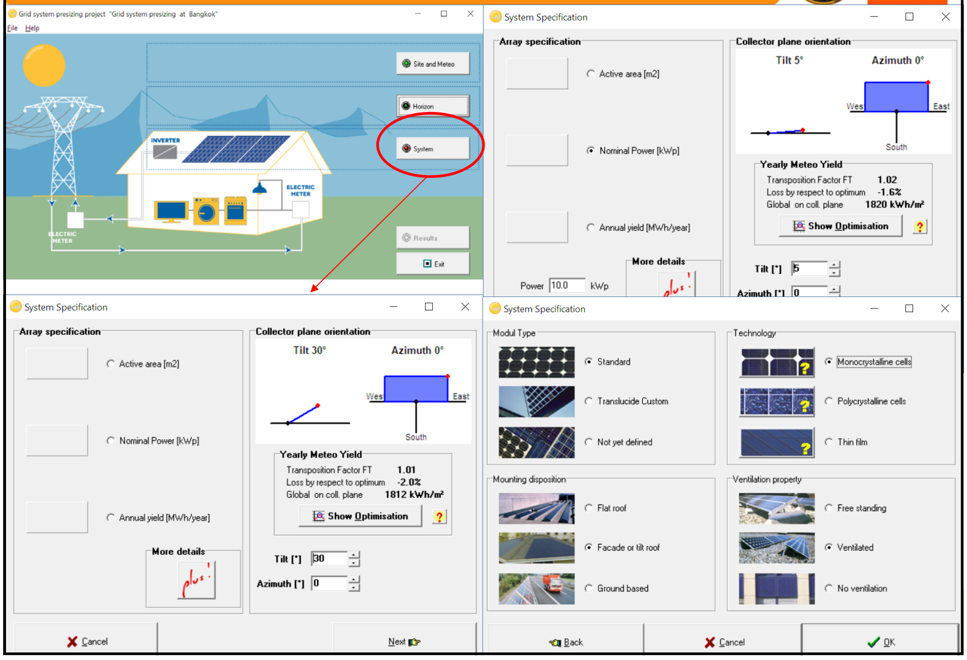
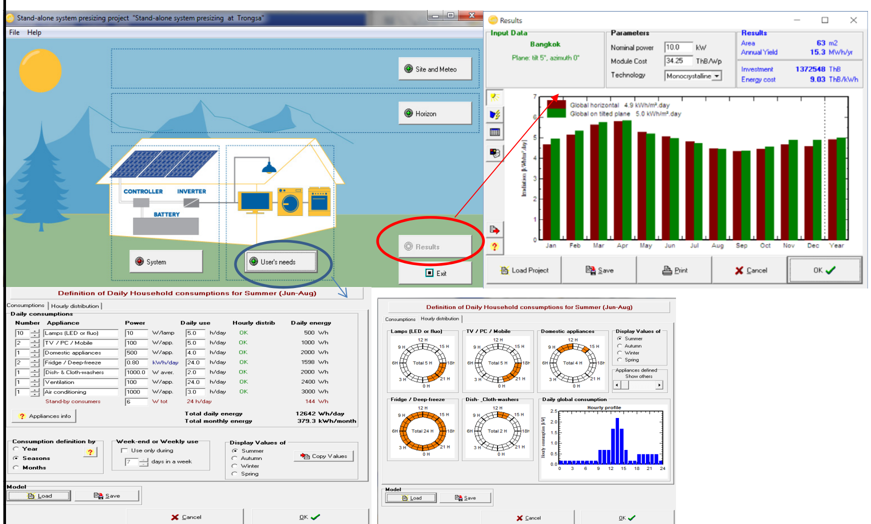


Concepts of PV System Design with PVsyst

Preliminary Design



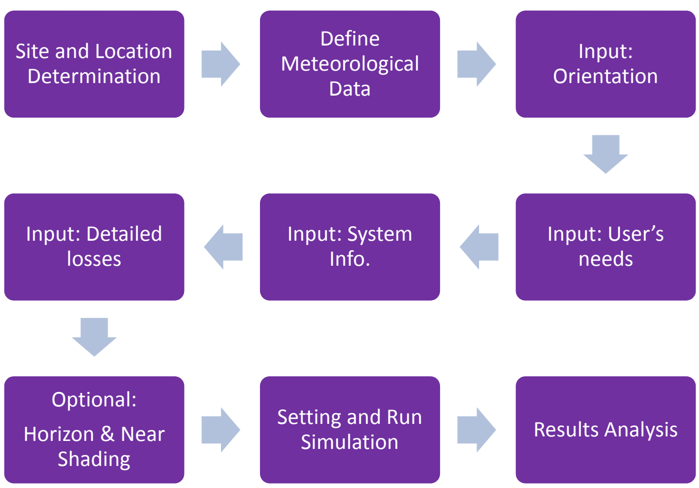
Concepts of PV System Design with PVsyst

Project Design

Project Design	Input								Optional					Simulation		
	Site & Meteo.	Orientation	User's needs	Water needs	System	Detailed losses	Self-consumption	Storage	Horizon	Near shading	Module Layout	Energy Manage	Economic Evaluation	Advance Simulation	Report	Detail Results
Grid-connected	•	•			•	•	•	•	•	•	•	•	•	•	•	•
Standalone	•	•	•		•	•			•	•			•	•	•	•
Pumping	•	•		•	•	•			•	•			•	•	•	•
DC Grid	•	•	•		•	•			•	•			•	•	•	•

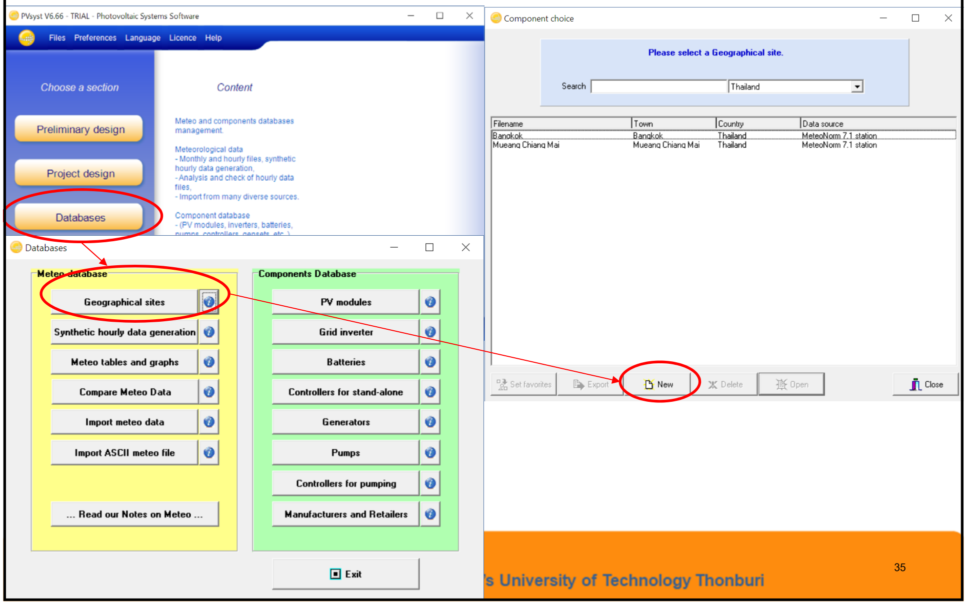
Concepts of PV System Design with PVsyst

Project Design



Concepts of PV System Design with PVsyst

Site and Location Determination



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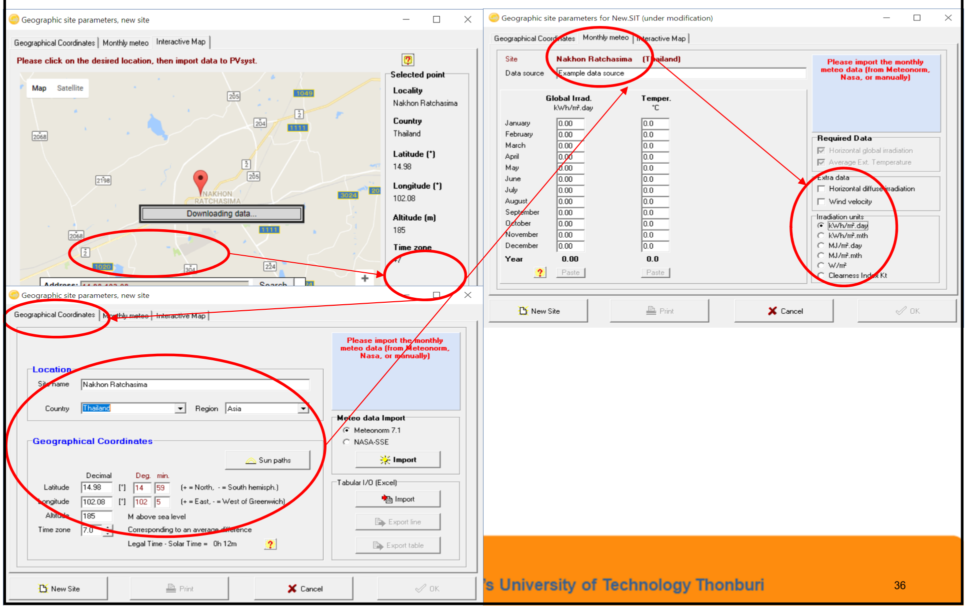
Concepts of PV System Design with PVsyst

Site and Location Determination ➡ Define Meteorological Data



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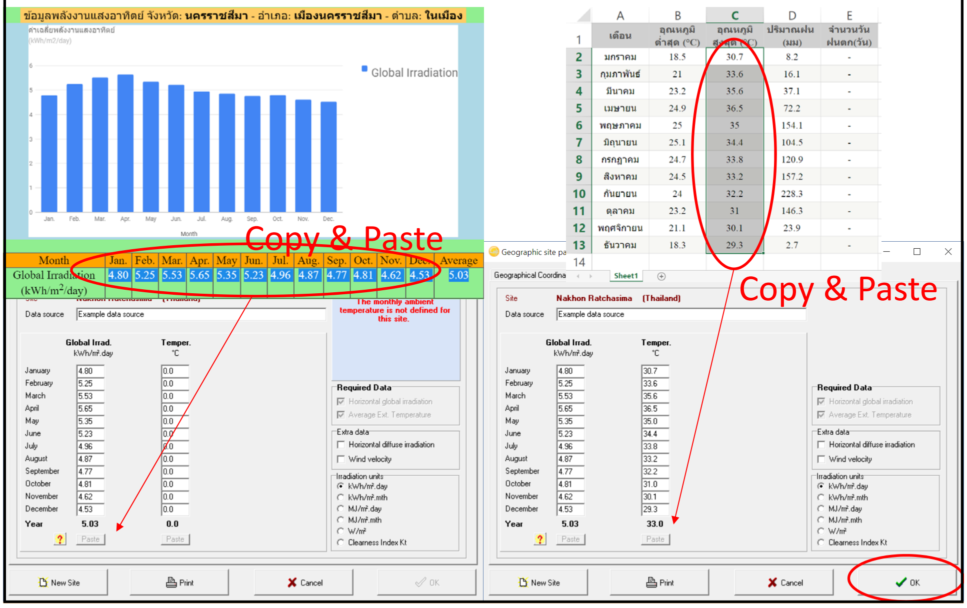
Concepts of PV System Design with PVsyst

Define Meteorological Data



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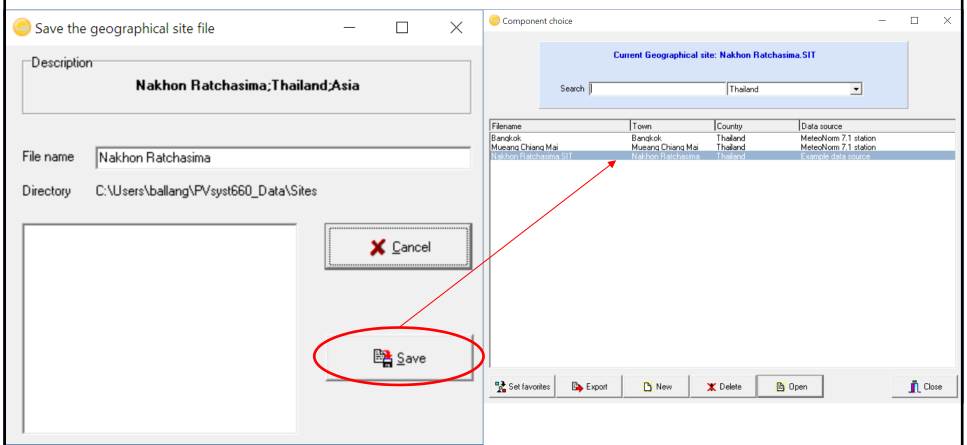
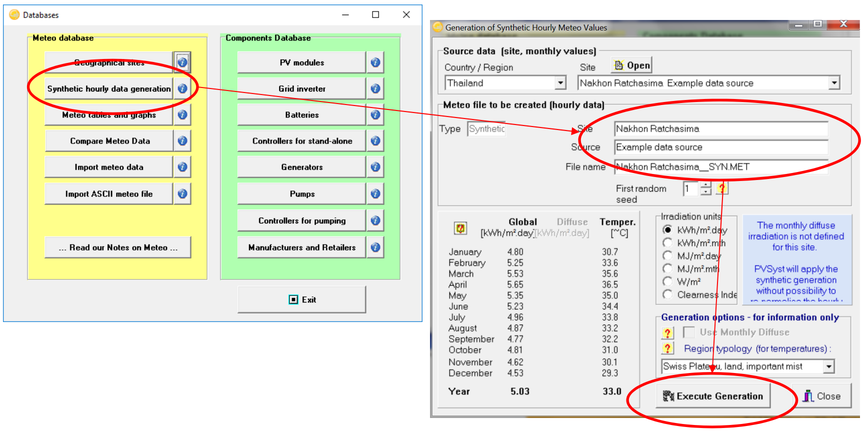


Concepts of PV System Design with PVsyst

Define Meteorological Data: Synthetic Hourly data generation



Concepts of PV System Design with PVsyst

Meteorological Data

Global Solar Radiation (Surface Measurement) Database		
World Radiation Data Center (WRDC)	WMO, Main Geophysical Observatory in St. Petersburg, Russia	1964 – present, >1000 stations, daily sums and monthly mean data
Baseline Surface Radiation Network (BSRN)	World Climate Research Program	~40 stations, high time resolution (1-3 minutes)
Integrated Information System		
Photovoltaic Geographical Information System (PVGIS)	Joint Research Center of the European Commission (JRC)	~566 stations, 1 km grid, 1981–1990 in Europe, HelioClim-1 in Africa
METEONORM	www.meteonorm.com	1961–1990 and 1981–2000, 1325 stations with irr, very high resolution (0.1–1 km)

Concepts of PV System Design with PVsyst

Meteorological Data

Online Satellite Database		
Satel-Light	European Union	Heliosat model, 1996 to 2000, Monthly average data
SoDa	MINES ParisTech	long-term time series of daily irradiation
SMSE or SSE	Surface Meteorology and Solar Energy (NASA)	200 satellite-derived meteorological parameters, 1 x 1°, 64800 regions from GOES
ABM	Australian Bureau of Meteorology	daily global solar irradiation from GMS-5, GOES-9, MTSAT-1R, MTSAT-2
SolarGIS	http://solargis.info/ by GEO Model SOLAR	Satellite data from Mateosat, GOES

http://re.jrc.ec.europa.eu/pvg_tools/en/tools.html

https://sam.nrel.gov/weather https://nsrdb.nrel.gov/nsrdb-viewer

Concepts of PV System Design with PVsyst

Summary of sources in Hourly values

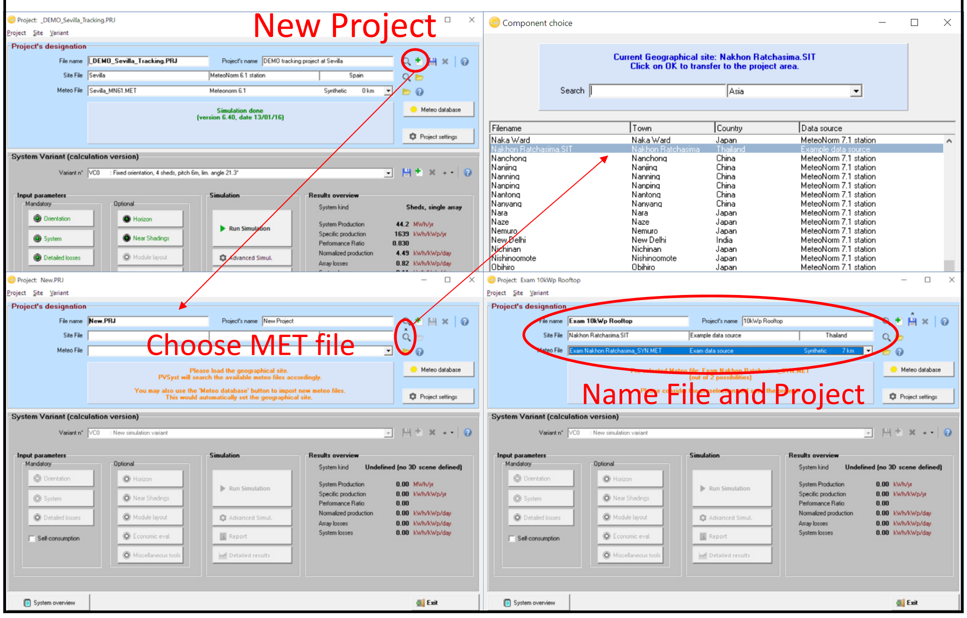
Database	Region	Values	Source	Period	Variables	Availability	PVsyst import
3Tier-Vaisala	Worldwide	Hourly	**Satellites** Spectroradiometer MODIS	**1998 - today**	GHI, DHI DNI available **no temper.**	**For pay**	Direct (file) .csv PVsyst format
Canada EPW	Canada	Hourly	CWEC, 80 **stations** Typical **M**eteo **Y**ears	**1953-1995** (samples)	GHI, DHI, TA WindVel	Web free	Direct (file) .EPW format
Explorador Solar	Chile	Hourly	**Satellites** Interp: 90x90 m²	**2004-2016** and **TMY**	GHI, DHI, TA WindVel	Web free	Direct (file) .csv Pvsyst format .csv SAM CSV format
Meteonorm	Worldwide	Hourly	**Synthetic** generation	**Reference**	GHI, DHI, TA Wind, RH	**Included in PVsyst V 6**	At site creation and available for sites from other sources
NREL TMY2/3 (NSRDB)	USA + Hawaii	Hourly	NREL, **1693 stations** Typical **M**eteo **Y**ears	**1991-2005**	GHI, DHI, TA WindVel	Web free	Direct (file) TMY2&TM3 format
NREL NSRDB Viewer	America 175°W to 25°W 20°S to 60°N	(Sub-) Hourly	**Satellites** 4x4 km² PSMv3 model	**1998-2016** and **TMY**	GHI, DHI, TA WindVel	Web free **Included in PVsyst V 6.76**	Direct (file) .csv SAM CSV format TMY at site creation (requires internet access)
	India and around 67°E to 98°E 5°N to 38°N	Hourly	**Satellites** 10x10 km² SUNY model	**2000-2014** and **TMY**	GHI, DHI, TA WindVel		
PVGIS v5	Worldwide	Hourly	**Satellites CM-SAF, SARAH or NSRDB**	**Reference TMY**	GHI, DHI, TA Wind, RH	Web **Included in PVsyst V 6.76**	TMY at site creation (requires internet access)
Satellight	Europe	Hourly	**Meteosat** Any pixel of about 5x7 km²	**1996-2000** 5 years only	GlobH **no temper.**	Web free	Direct (file) .tsv format
Soda-Helioclim3	Europe Africa	Hourly	**Meteosat**	**2004 - today**	GlobH **no temper.**	Web **For pay** 2004/5 free	Direct by copy/paste or .csv PVsyst format
Solar Anywhere (SUNY model)	USA + Hawaii	Hourly	**Satellites** 10x8 km²	**1998 - today**	GlobH, DiffH Temp. for pay Wind for pay	Web 2010 - today for pay	Direct (file) native + PVsyst format
Solargis	Worldwide	Hourly	**Meteosat, ERA**	**1994 - today**	GHI, DHI, TA	**For pay**	Direct (file) native + PVsyst format
Solar Prospector (SUNY Model)	USA	Hourly	**Satellites**	**1998 - 2009**	GHI, DHI, DNI TA, WindVel	Web No more available	Direct (file) TMY2 format
Vortex Solar	Worldwide	Hourly	**Satellites**	**1997 - today**	GHI, DHI, TA	**For pay**	Direct (file) .csv PVsyst format

Concepts of PV System Design with PVsyst

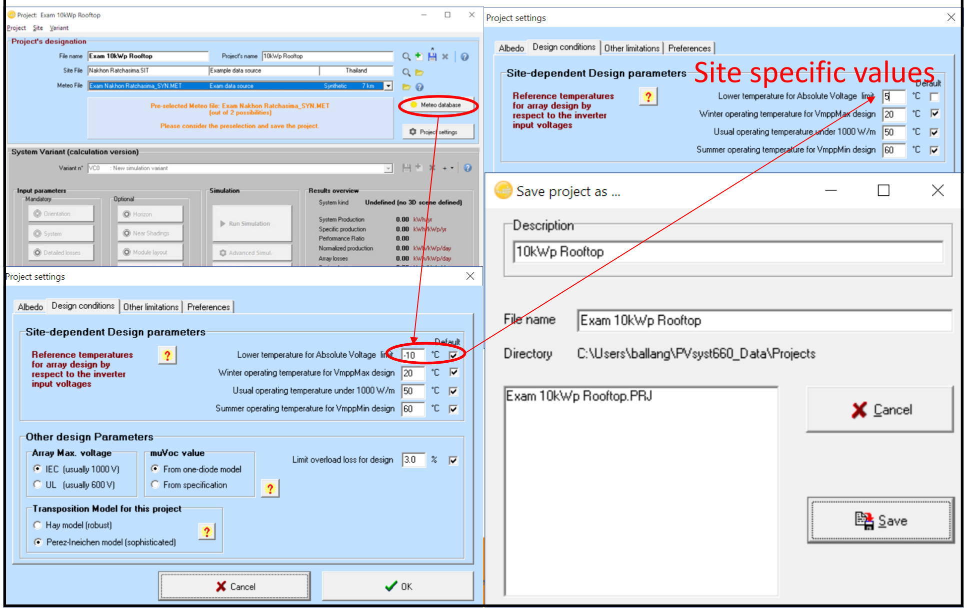
Meteorological Data (Monthly Data)

Database	Region	Values	Source	Period	Variables	Availability	PVsyst import
Meteonorm	Worldwide	Monthly	**1'200 Terrestrial stations** (+ complement satellite) Interpolations	**1960-1991** averages V 6.1: **1995-2005** (optional)	GlobH Temp. Wind Others	**Included in PVsyst V 6** Software	Direct by site choice Direct by hourly file
Meteonorm 7.2	Worldwide	Monthly	**2'500 Terrestrial stations** (+ complement satellite)	**1961 - up to 2015 for some countries**	GHI, DHI, TA Wind, RH, Linke turbidity	Software, for pay **Included since PVsyst V6.7.3**	Direct import - hourly file Included stations or at site creation
NASA-SSE (old data)	Worldwide	Monthly	**Satellites** 1°x1° cells (111 km)	**1983-2005** averages	GlobH Temp	Web, free **Included in Pvsyst**	At site creation
RETScreen	Worldwide	Monthly	Compil. 20 sources incl. WRDC - NASA	**1961-1990** (averages)	GlobH, TA WindVel	Software, free	Direct by copy/paste
Solargis	Worldwide	Monthly	**Meteosat, ERA**	**1994 - today**	GHI, DHI, TA	For pay	Direct (file) .csv native format
WRDC (old database)	Worldwide	Hourly Daily Monthly	1195 stations	**1964-1993** (each)	GlobH no temper.	Web free	Direct by copy/paste

Concepts of PV System Design with PVsyst

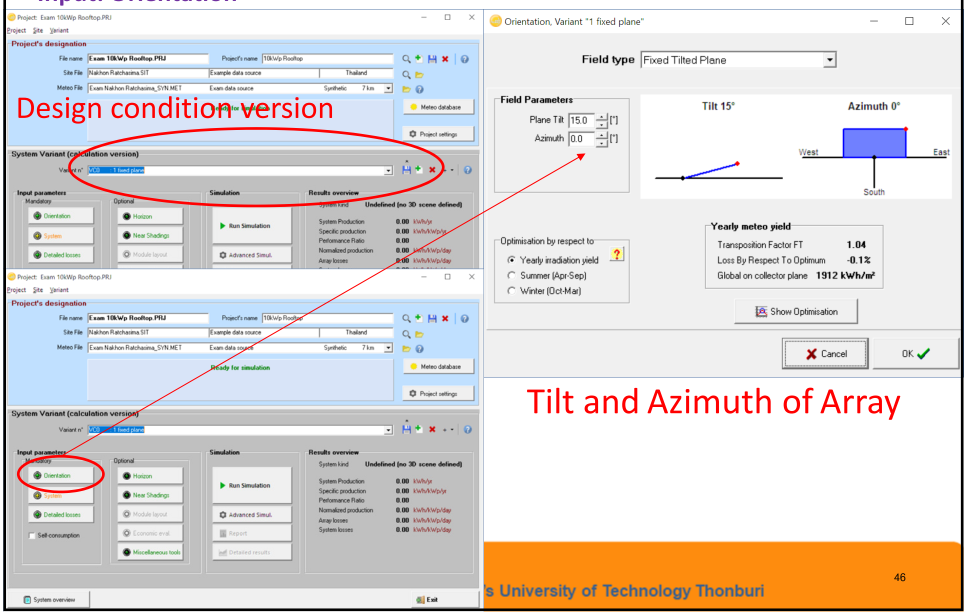


Concepts of PV System Design with PVsyst



Concepts of PV System Design with PVsyst

Input: Orientation



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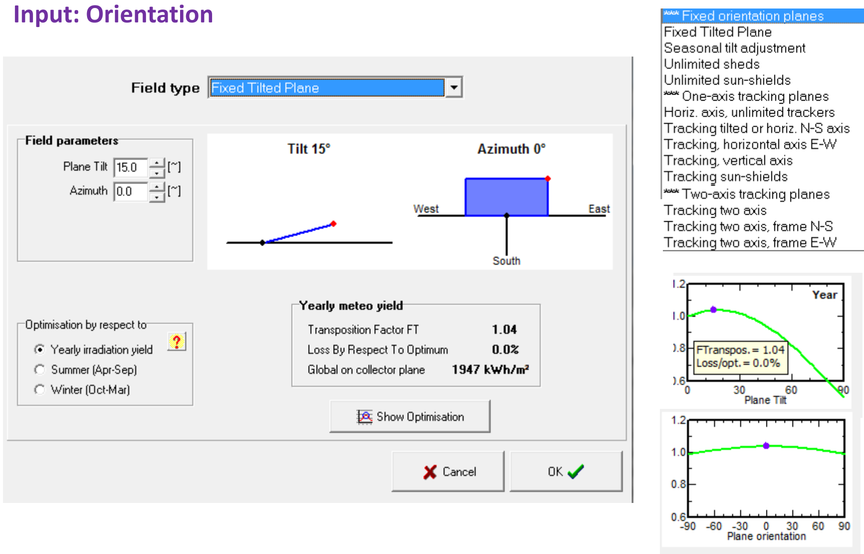
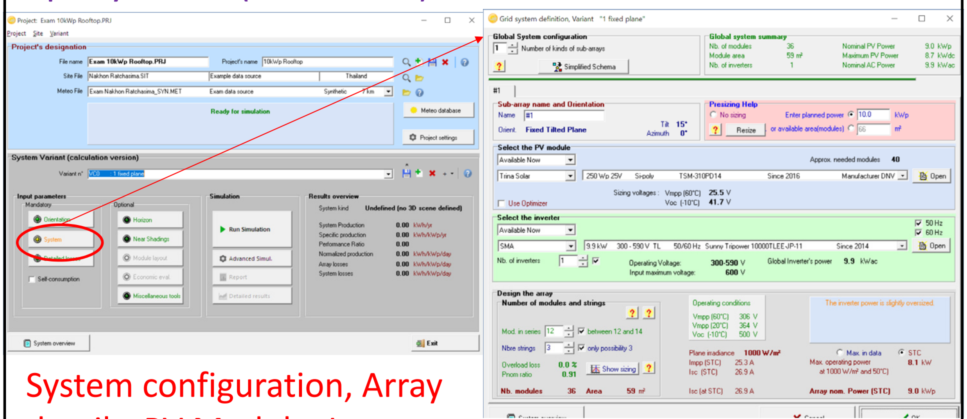
Concepts of PV System Design with PVsyst

Input: Orientation



Concepts of PV System Design with PVsyst

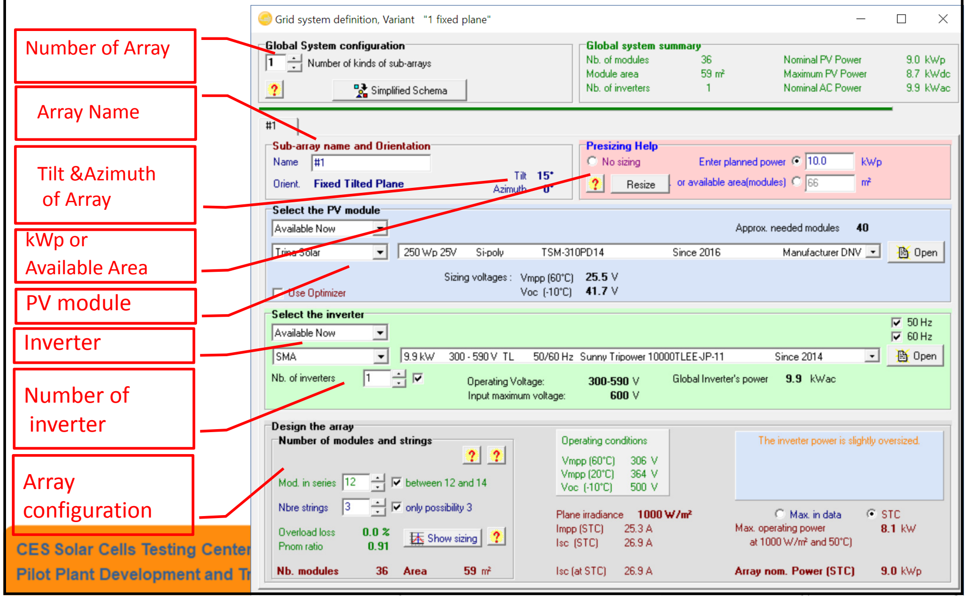
Input: System Info. (Grid-connected)



System configuration, Array details, PV Module, Inverter

Concepts of PV System Design with PVsyst

Input: System Info. (Grid-connected)



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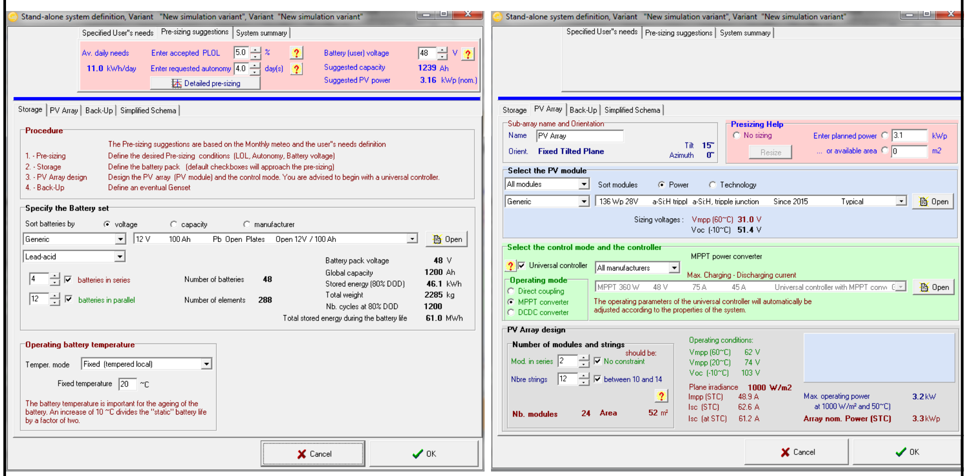
Pilot Plant Development and Tr

Concepts of PV System Design with PVsyst

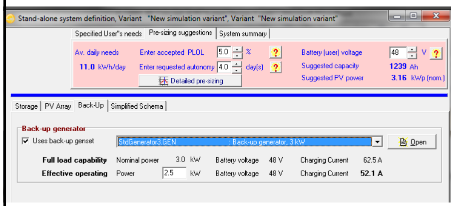
Input: System Info. (Standalone)

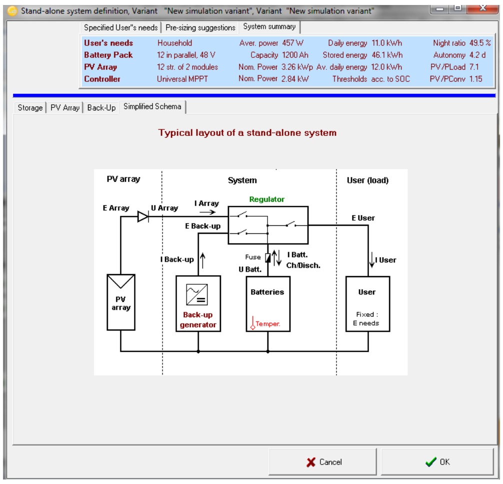


CES Solar Cells Testing Center (CSSC)
Pilot Plant Development and Training Institute, King Mongkut's University of Technology Thonburi

Concepts of PV System Design with PVsyst

Input: System Info. (Standalone)





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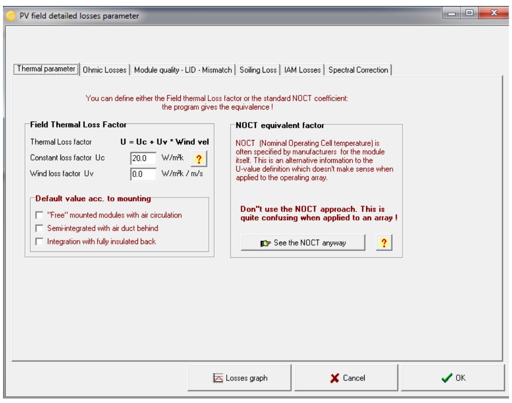
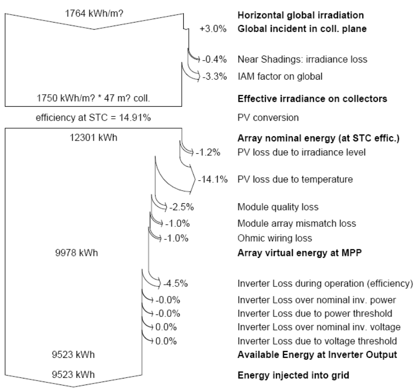
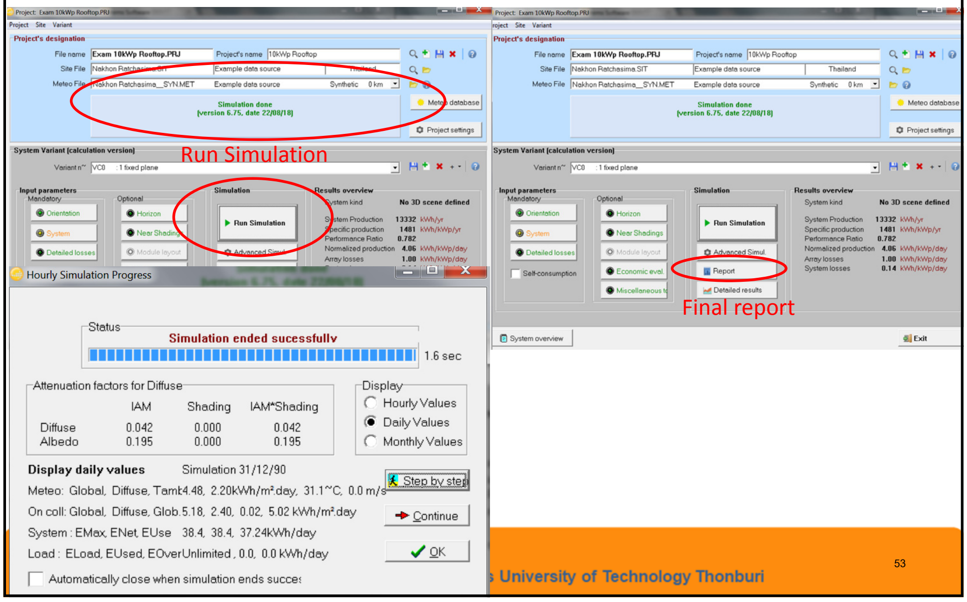
Input: Detailed losses





Concepts of PV System Design with PVsyst

Run Simulation



Concepts of PV System Design with PVsyst

Results Analysis

PVSYST V6.75 | 22/08/18 | Page 1/3

Grid-Connected System: Simulation parameters

Project : 10kWp Rooftop

Geographical Site Nakhon Ratchasima — Country Thailand
Situation Latitude 14.98° N — Longitude 102.08° E
Time defined as Legal Time Time zone UT+7 — Altitude 185 m
Albedo 0.20
Meteo data: Nakhon Ratchasima Example data source - Synthetic

Simulation variant : 1 fixed plane
Simulation date 22/08/18 22h52

Simulation parameters System type No 3D scene defined
Collector Plane Orientation Tilt 15° — Azimuth 0°
Models used Transposition Perez — Diffuse Perez, Meteonorm
Horizon Free Horizon
Near Shadings No Shadings

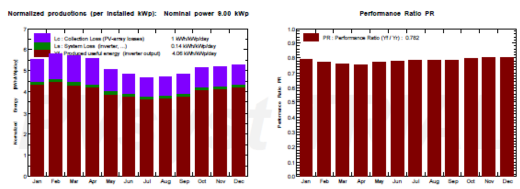
PV Array Characteristics
PV module Si-poly Model TSM-310PD14
Original PVsyst database Manufacturer Trina Solar
Number of PV modules In series 12 modules — In parallel 3 strings
Total number of PV modules Nb. modules 36 — Unit Nom. Power 250 Wp
Array global power Nominal (STC) 9.00 kWp — At operating cond. 8.09 kWp (50°C)
Array operating characteristics (50°C) U mpp 320 V — I mpp 25 A
Total area Module area 59.2 m² — Cell area 52.6 m²

Inverter Model Sunny Tripower 10000TLEE-JP-11
Original PVsyst database Manufacturer SMA
Characteristics Operating Voltage 300-590 V — Unit Nom. Power 9.90 kWac
Inverter pack Nb. of inverters 1 units — Total Power 9.9 kWac
Pnom ratio 0.91

PV Array loss factors
Thermal Loss factor Uc (const) 20.0 W/m²K — Uv (wind) 0.0 W/m²K / m/s
Wiring Ohmic Loss Global array res. 212 mOhm — Loss Fraction 1.5 % at STC
Module Quality Loss — Loss Fraction -0.5 %
Module Mismatch Losses — Loss Fraction 1.0 % at MPP
Strings Mismatch loss — Loss Fraction 0.10 %
Incidence effect, ASHRAE parametrization IAM = 1 - bo (1/cos i - 1) — bo Param. 0.05

User's needs : Unlimited load (grid)

Main simulation results
System Production — Produced Energy 13.33 MWh/year — Specific prod. 1481 kWh/kWp/year
Performance Ratio PR 78.16 %



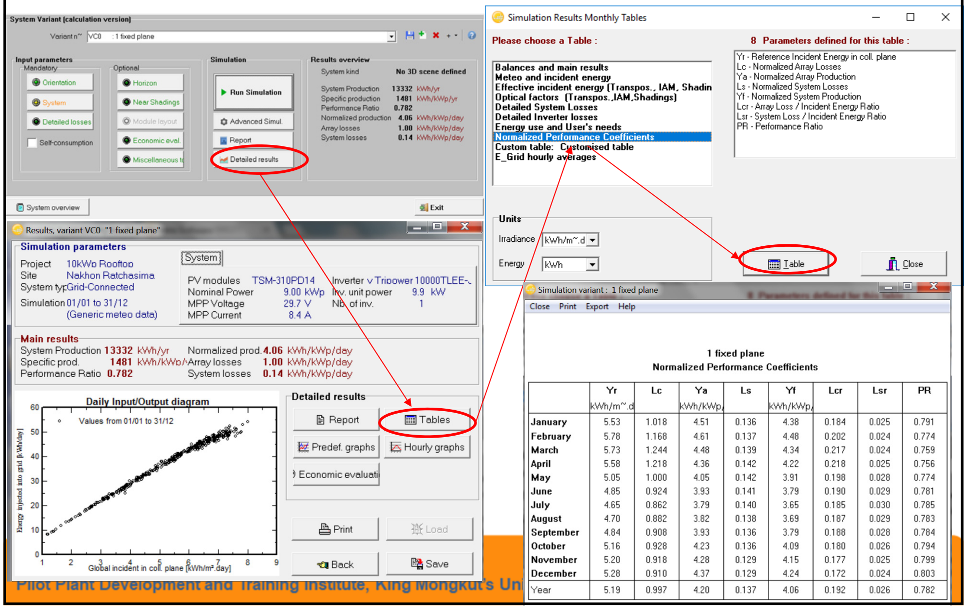
1 fixed plane
Balances and main results

	GlobHor kWh/m²	DiffHor kWh/m²	T Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray MWh	E_Grid MWh	PR
January	148.8	60.45	30.70	171.5	166.4	1.260	1.222	0.791
February	147.0	65.40	33.60	161.9	157.0	1.162	1.128	0.774
March	171.4	80.36	35.60	177.6	172.1	1.251	1.212	0.759
April	169.5	78.83	36.50	167.3	162.0	1.177	1.139	0.756
May	165.9	83.32	35.00	156.6	150.9	1.131	1.091	0.774
June	156.9	81.58	34.40	145.6	140.1	1.061	1.023	0.781
July	153.8	86.53	33.80	144.3	138.9	1.058	1.019	0.785
August	151.0	82.98	33.20	145.8	140.7	1.067	1.028	0.783
September	143.1	74.10	32.20	145.1	140.5	1.061	1.024	0.784
October	149.1	75.60	31.00	159.9	155.1	1.180	1.142	0.794
November	138.6	62.54	30.10	155.9	151.1	1.156	1.121	0.799
December	140.4	58.33	29.30	163.6	158.6	1.218	1.182	0.803
Year	1835.5	890.02	32.94	1895.2	1833.5	13.782	13.332	0.782

Legends:
GlobHor — Horizontal global irradiation
DiffHor — Horizontal diffuse irradiation
T Amb — Ambient Temperature
GlobInc — Global incident in coll. plane
GlobEff — Effective Global, corr. for IAM and shadings
EArray — Effective energy at the output of the array
E_Grid — Energy injected into grid
PR — Performance Ratio

Concepts of PV System Design with PVsyst

Results Analysis



Concepts of PV System Design with PVsyst

Results Analysis

1 fixed plane
Normalized Performance Coefficients

	Yr kWh/m².d	Lc	Ya kWh/kWp	Ls	Yf kWh/kWp	Lcr	Lsr	PR
January	5.53	1.018	4.51	0.136	4.38	0.184	0.025	0.791
February	5.78	1.168	4.61	0.137	4.48	0.202	0.024	0.774
March	5.73	1.244	4.48	0.139	4.34	0.217	0.024	0.759
April	5.58	1.218	4.36	0.142	4.22	0.218	0.025	0.756
May	5.05	1.000	4.05	0.142	3.91	0.198	0.028	0.774
June	4.85	0.924	3.93	0.141	3.79	0.190	0.029	0.781
July	4.65	0.862	3.79	0.140	3.65	0.185	0.030	0.785
August	4.70	0.882	3.82	0.138	3.69	0.187	0.029	0.783
September	4.84	0.908	3.93	0.136	3.79	0.188	0.028	0.784
October	5.16	0.928	4.23	0.136	4.09	0.180	0.026	0.794
November	5.20	0.918	4.28	0.129	4.15	0.177	0.025	0.799
December	5.28	0.910	4.37	0.129	4.24	0.172	0.024	0.803
Year	5.19	0.997	4.20	0.137	4.06	0.192	0.026	0.782

Concepts of PV System Design with PVsyst

Results Analysis

Performance Parameters in PVsyst

- Yr : Reference Incident Energy in coll. Plane
- Lc : Normalized Array Losses
- Ya : Normalized Array Production
- Ls : Normalized System Losses
- Yf : Normalized System Production
- Lcr : Array Loss/ Incident Energy ratio
- Lsr : System Loss/ Incident Energy ratio
- PR : Performance Ratio

✓ Thermal losses
✓ Ohmic wiring losses
✓ Module quality losses
✓ Incidence angle losses

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Concepts of PV System Design with PVsyst

IEC 61724 ed2-2017 : Photovoltaic system performance monitoring-Part1: Monitoring

- Yr : Reference yield

meaning : Total in-plane irradiation (H_i) divided by module's reference plane of array irradiance ($G_{i,ref}$)

- Ya : PV array energy yield

meaning : Array DC energy output (E_A) divided by installed PV array (P_o)

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Concepts of PV System Design with PVsyst

IEC 61724 ed2-2017 : Photovoltaic system performance monitoring-Part1: Monitoring

- Yf : Final system yield

meaning (For grid-tied): net AC energy output (E_{out}) of entire PV system divided by the installed PV array power (P_o)

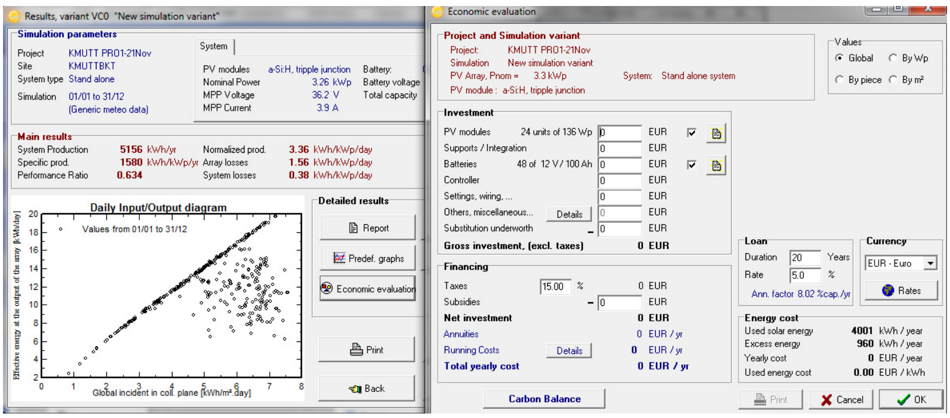
- PR : Performance ratio

meaning : The over all effect of losses on the system output due to the array temperature, system loss, failure etc.

$$PR = Y_f/Y_r$$

Concepts of PV System Design with PVsyst

Results Analysis: Economic Evaluation

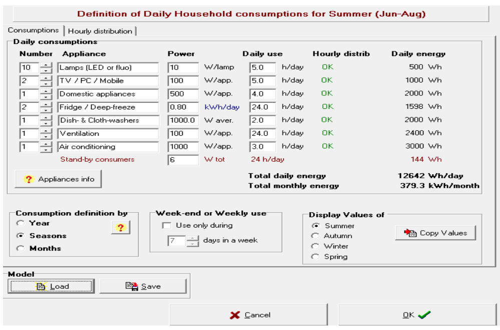


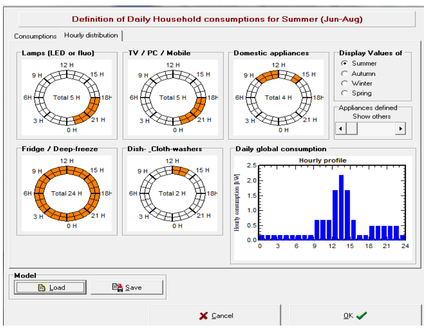
Exercises with PVsyst

Exercises with PVsyst

Load consumption

Use example: template household 12kWh/d

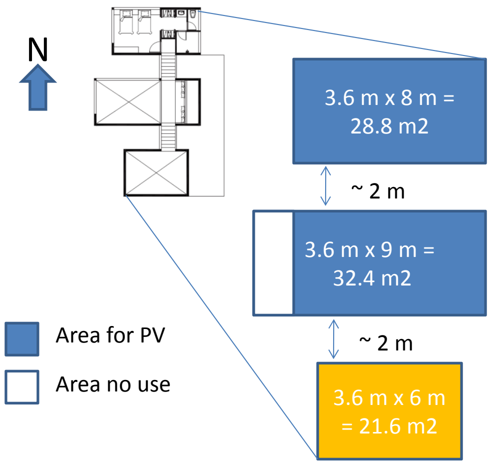




1. Design standalone PV system over the limited roof area.
Lead Acid Batt. LOL 5%, Autonomy 4 days, Battery voltage 48V
PV Array Operation mode: MPPT
Generator Back-up 3kW Effective 2.5kW
Location: at home!

Exercises with PVsyst

Available Area for PV Installation



Roof	Area	Tilt/Azimuth
Roof No.1	28.8 m2	10/0
Roof No.2	32.4 m2	0/0
Roof No.3	21.6 m2	0/0
Total	**82.8 m2**	
Area for PV	**57.6 m2**	

Exercises with PVsyst

2. Design Grid-connected PV system on full area over the same roof and same place.
No storage, Not self-consumption
Horizon: Azimuth/Height 120/10 , -40/15
Without near shading

Report the Balance and Main results