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Review Article

Review and Analysis of Solar Photovoltaic Softwares

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Abstract

In this paper we have presented all the Photovoltaic simulation software that is available in market for commercial application as well as for educational and research purpose till date. For this an extensive search was made to providing all the details of Photovoltaic simulation software presented in this paper. The investigated simulation software's were evaluated according to the following criteria.
P1 their commercial and educational availability and cost
P2 their working platform
P3 their working capacities
P4 their scope and output
P5 their updatability

Keywords: *Simulation, Photovoltaic, Grid connected system, software*

1. Introduction

Simulation is the realization of the real word process or system. It is a technique for modeling and investigating the system or process performance. Simulation has got a lot of application in across the fields i.e. Computer and Communication system, Manufacturing and Material handling, Automobile industry, Transportation, Health care and many more fields. Recent advancements and technical development in the field of simulation modeling made it popular. Today simulation is the most widely used and accepted tool in the system analysis, research and development. Today's market continuously increasing in the number of simulation software available and the reach of these simulation software becomes more easy due to available in simple languages and many languages. That is the reason market has specific simulation software for specific task, if one has to design grid connected PV system, then there will be specific or separate simulation software for corresponding task.

There are around fifty small or large simulation software they basically categorized in simulation tool, economic evaluation tools, photovoltaic industry related tools, analysis and planning tools, monitoring and control tools, solar radiation maps and some other online software. Simulation tools are INSEL and TRNSYS. Economic evaluation tools are HOMER, Solar Advisor Model (SAM), RETScreen, SOLinvest and EnergyPeriscope. Photovoltaic industry related tools are APOS photovoltaic StatLab, Organic Photovoltaics Analysis Platform and PV Cost Simulation Tool. Analysis and planning tools are pvPlanner, Archelios, String Design Tool, PV*SOL, BlueSol, PV F-CHART, Solmetric PV Designer, DDS-CAD PV, Polysun, REA System Sizing Tool, PVSYST, Solar Pro, PV Professional, Solarius-PV and Matel Grid. Monitoring and Control Tools are Meteocontrols, SPYCE, pvspot, Autodesk ECOTECT Analysis, METEONORM, Shadow Analyser, Shadows, Amethyst ShadowFX, Sombrero, Panorama master, Horizon, GOSOL and Skelion. Solar radiation maps are Focus Solar, SolarGIS, 3TIER and PVGIS. Some online softwares are PV-Phil, SolarDesignTool, oTilt, PVwizard, Logiciel CalSol.

This paper presents all major Solar PV simulation software available in market basically major simulation software and presents all the evaluation parameters of these simulation software's.

2. Important Solar PV Simulation Software

The detailed description of all major software as below along with specific selection criteria

2.1 Photo Voltaic systems (PVsyst)

PVsyst can be used to simulate grid connected, stand alone and pumping system. It is a PC based software and can be installed in any version of Window or any operating system. It can be used by architecture, engineers and researchers. The new PVsyst Version 6.16 is available in market; it operated in three modes full license, evaluation mode and demo mode.

P1 their commercial and educational availability and

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cost: PVsyst available in two types one is PRO30 limited to 30kW installation only and PREMIUM all installation. Cost of PRO30 CHF 1000 for one machine additional CHF 700 for second machine and additional CHF 500 for third machine respectively. Cost of PREMIUM CHF1300 additional CHF 1000 for second machine and CHF 700 for third machine respectively.

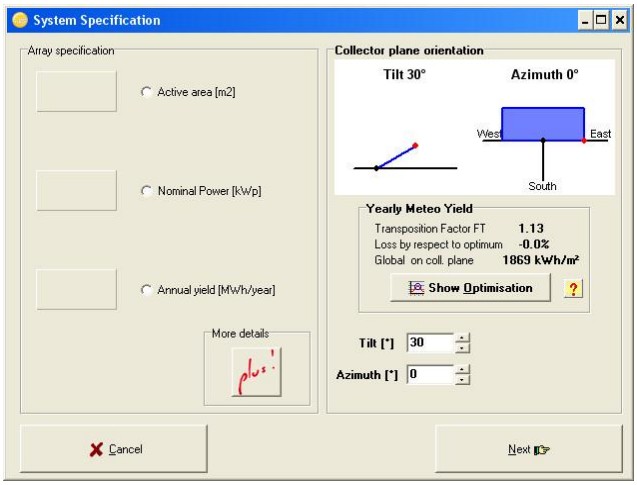

Fig.1 PVsyst screen showing simulation optimization

P2 their working platform: Windows 8, Windows 7, Vista, XP (older versions of Windows NT, 98, 95). 32-bits and 64-bits processors. MAC OSX (see here) and Linux with a virtual machine running Windows 32-bits (e.g., Virtual Box). Windows servers are not supported.

P3 their working capacities: PVsyst provide multiple choices to user for project design like preliminary design, project design, data base and tools. Preliminary design is the pre-sizing step of a project. It is aimed to quickly define the general features of a planned PV system.

In this mode of operation the system yield evaluations are performed very quickly in monthly values, only defining a very few general system characteristics, without defined specific system components. We can roughly estimation of the system cost is also available. Project design is aiming perform a thorough PV-system design and performance analysis using detailed hourly simulations. These are organised in the framework of a Project, which essentially holds the geographical condition, location and meteorological hourly data. Optimizations and parameter analysis can be performed through different simulation runs, called variants. Tools include the meteo database, with graphical displays or tables and components.

P4 their scope and output: PVsyst provide a very good platform for all type of need to analysis project more effectively for this various provision given in PVsyst 6.19. The mainly two function given in PVsyst front window like database and tools, database provide detail regarding Geographical sites, synthetic hourly data generation, meteo tables and graphs, import meteo data, import ASCII meteo data in component database it provide details like PV modules, grid inverter, batteries, regulators for stand-alone, generators, pups, regulators for pumps, and many more details regarding manufacturers and retailers.

P5 their updatability: Yes latest version (PVsyst6.19) released on February 11, 2014

2.2 Renewable Energy Technologies Screen (RETScreen)

Renewable energy technology screen is developed by Canadian Government, industry and academia. It is free of cost tool for all industry, academia and researcher in the field of renewable energy. It has two separate program one is RETScreen 4 and RETScreen plus. RETScreen 4 is excel based renewable energy software tool that can be used to technical as well as financial visibility of renewable potential, energy efficiency and cogeneration projects.

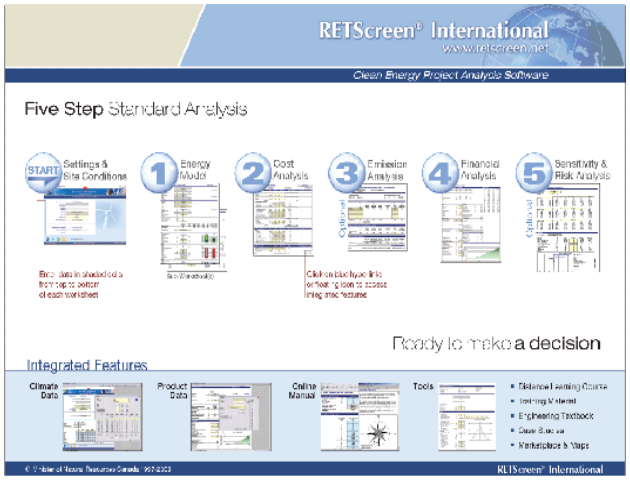

Fig.2 RETScreen shows steps to standard analysis

RETScreen plus is a window based energy management software tool that provide details regarding energy performance of ongoing project to owners.

P1 their commercial and educational availability and cost: Free of cost

P2 their working platform: The program requires the use of Microsoft Excel 2003 or higher version; Microsoft Windows XP or higher windows platform; and Microsoft .NET Framework 4 or higher (note that the Full Profile version must be installed, not just the Microsoft .NET Framework 4 Client Profile Version.) It can also work on Apple Macintosh computers using Parallels or VirtualBox for Mac. RETScreen Plus is Windows-based and independent of Microsoft Excel.

P3 their working capacities: This soft is available more than 36 languages that mean its cover almost 2/3rd population of word. This provide various project facility like energy efficiency measure, power, heating, cooling, combined heating & cooling, combined cooling & power many more. Technology can be used are photovoltaic, reciprocating engine, solar thermal power, steam engine, steam turbine, tidal power, wave power.

P4 their scope and output: RETScreen provide detail regarding proposed power generation, emission analysis, and financial analysis. RETScreen plus provide a power full tool it provide option to select climate data from vast meteo database. In data option it provides three steps. Step 1 consumption and production, where we can calculate

electricity consumption, fuel consumption, water consumption, and electricity production and some user defined data. Step 2 provides facility regarding weather, production level and occupancy. Step 3 provides degree days, daily solar radiation and tilted angle.

P5 their updatability: Yes, an updated version of RETScreen 4 and RETScreen plus was released on September 25, 2012.

2.3 Hybrid Optimization Model for Electric renewables (HOMER)

HOMER is a computer based that simplified model for designing of distributed generation (DG) systems both on and off-grid. HOMER's optimization and sensitivity analysis algorithms allow user interface to evaluate the economic and technical feasibility of a large number of technology options and to account for variations in technology costs and energy resource availability.

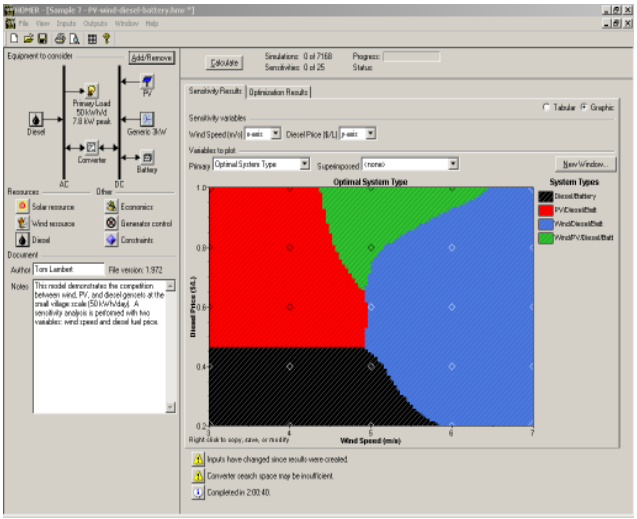

Fig.3 User interface window of HOMER

P1 their commercial and educational availability and cost: HOMER 2 is $99.99 for as on date and with 6-month license. The 6-month license price will increase to $150 from April 1, 2014.

P2 their working platform: HOMER can be installed on all versions of Microsoft windows and Windows emulators.as parallels for Macintosh.

P3 their working capacities: HOMER basically performs three functions namely Sensitivity analysis, optimization and simulation in distributed generation system. It helps to design micro power systems. It contains a very powerful computation engine as well as a logical unit and true interface between the system and user. That's why it can perform or simulate thousands of system constellations in a trice and optimize for life cycle costs.

This can be simply used by non-engineers users likewise masters etc.

It provides three functions model for both conventional and renewable energy technologies: power source i.e solar photovoltaic, wind turbine, run of river hydro power electric utility grid micro turbine, fuel cell, and generator: diesel, gasoline, biogas, alternative and custom fuels, cofired. Storage: battery bank, hydrogen, flow batteries, flywheels. Loads: daily profiles with seasonal variation, deferrable (water pumping, refrigeration), thermal (space heating, crop drying), efficiency measures

P5 their updatability: Yes. Latest version 2.81 of HOMER 2 was released on November 8, 2010 and the first version (original) was released on February 14, 2000.

2.4 TRaNsient Systems Simulation (TRNSYS)

TRNSYS is an extremely flexible graphic based software environment that is used to simulate the behavior of the transient system mainly. While the other majority of simulations software is focused on assessing the performance of the thermal and electrical energy system.

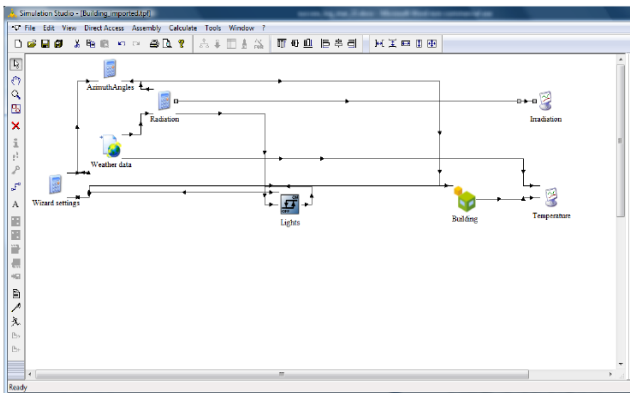

Fig.4 Simulation window of TRANSYS system

This was evolved in 1975 by international collaboration of the United States, France and Germany initially. It is available for both commercial as well educational applications.

P1 their commercial and educational availability and cost: Latest version is TRNSYS 17 that is available for $4740 for single user and $ 7700 for five users. For educational purpose it is available for $2370 for ten users and $3850 for 20 users.

P2 their working platform: Only windows operating system (XP/Vista/Window 7) can be used to run TRNSYS. If someone wants to create their own TRNSYS components to use their simulation then FORTRAN compiler required.

P3 their working capacities: TRNSYS is available in different suit like TRANSYS3D allow user to draw multizone building and import the geometry including self-shading, TRNBUILD allow user for creating and editing all of the non-geometry information required, TRNEDIT is a full-featured text editor for writing and viewing TRNSYS input and output files and for upcoming parametric and TRNSED allow user to create customized graphic for specific application and then distribute those application to non-TRNSYS users.

P4 their scope and output: The TRNSYS is robust, intuitive, graphical front end for the simulation, making the user's job of assembling of a detailed system in a simple endeavor. The output of one component is graphically connected to the inputs of another. Users can watch the value of ANY system variable on an online plot

as the simulation progresses. Output devices also allow the user great flexibility in integrating, and reporting any component output value.

P5 their updatability: Yes. Latest version of TRNSYS is available in market TRNSYS 17.1 was released in June 2012.

2.5 INtegarted Simulation Environment Language (INSEL)

INSEL is graphical programming language for common objective in integrated simulation environment by INSEL we can solve any of computer simulation problem for photovoltaic systems.

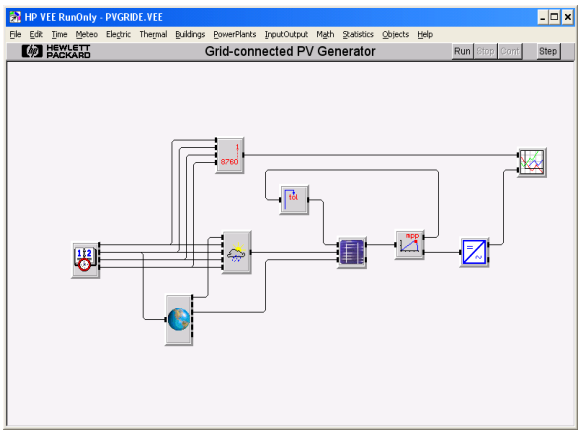

Fig.5 INSEL simulation window for grid connected system

It provides functional block diagram for the simulation of meteorological data, thermal energy and electrical constituents which is a strong right answer for the simulation problems. It works basically as a modular simulation environment for understand, plan, monitor and visualize energy systems.

P1 their commercial and educational availability and cost: Cost of INSEL for single user is $2023 and $ 6069 for five-user license. Cost for research and education institutes is $ 1011 for single user and 3034 for five-user. Student version is available only for $101.

P2 their working platform: Windows XP, Windows Vista or Windows 7 computers with 32 or 64 bit.

P3 their working capacities: Using the graphical tool of INSEL, we can develop full visualization and monitoring of your energy plant. Simulation model can be made easily with graphic editor with some mouse click. It works with database for photovoltaic modules, inverters, thermal collectors and meteorological condition. INSEL offers a programing interface for the extension of block library.

P4 their scope and output: INSEL contains a variety of application like graphical and numerical output either user defined or built in. It covers solar irradiance simulation, photovoltaic, and solar thermal applications. We can see 1-axis tracking, 2-axis tracking and losses for tilted fixed angles.

P5 their updatability: Yes. Latest version 8.1 is available.

2.6 Photovoltaic F-Chart (PV F-Chart)

PV F-chart is a photovoltaic system for design and analysis that include almost all aspect of system analysis. PV F-chart is an implementation method developed at the University of Wisconsin Solar Energy Laboratory to estimate long-term average performance of utility interface systems, battery storage systems and system with no interface or battery storage i.e battery storage system.

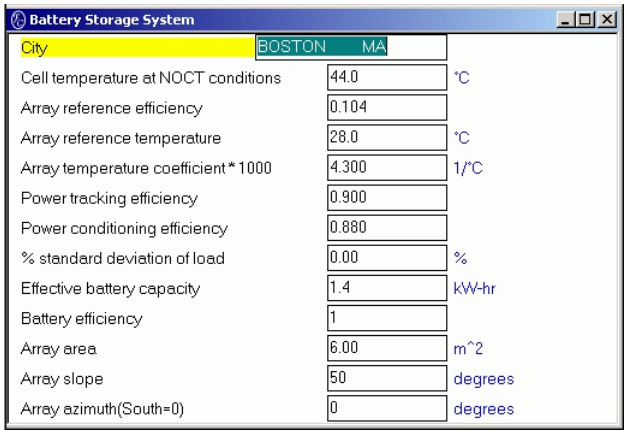

Fig.6 PV F-chart window to select different parameters

P1 their commercial and educational availability and cost: Single user license $400 and academic $600.
P2 their working platform: PV F-chart can be run on all version Windows.

P3 their working capacities: PV F-chart has a good collection of data over 300 location data are stored in PV F-chart and more location can be included at user level. Using this software we can model utility system battery system and stand-alone photovoltaic systems. The main feature of PV F-chart includes fast execution, hourly load profiles for each month, buy/sell coat difference and statistical load variation**.**

P4 their scope and output: PV F-chart shows the energy production and saving, system performance results, solar fraction, efficiency, electricity sold, electricity bought, life cycle saving, life cycle cost, greenhouse gases emission reduction for various energy efficient and renewable technologies and finally financial viability and risk for central-grid, isolated-grid and off-grid.
P5 their updatability: Yes

2.7 National Renewable Energy Laboratory Solar Advisor Model (NREL SAM)

IT is designed for performance and economic analysis of renewable energy projects; it is best suit to the people involved in renewable energy industries. NREL SAM is best suitable to the project managers and engineers, policy analysis, technology developers and researchers.

SAM predicts the performance and cost of the project is based on installation and operating cost of the project.

P1 their commercial and educational availability and cost: Free of cost

*P2 their working platform***:** Windows 7/8/Vista or Operating system X 10.6 Intel or later.

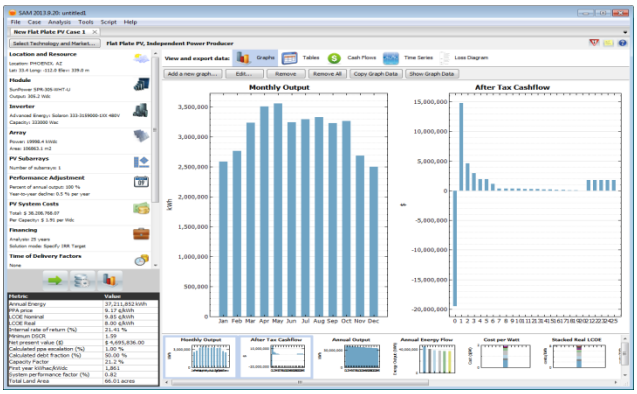

Fig.7 SAM window showing monthly generation

P3 their working capacities: NREL SAM is a System-Driven Approach and solar energy technologies program technology. System-Driven Approach is very useful for effective resource allocation. Performance model of SAM include the following technologies: Photovoltaic system, parabolic trough concentrating solar power, power tower concentrating solar power, Fresnel concentrating solar power, dish-stirling concentrating solar power, conventional thermal, solar water heating for residential or commercial buildings, large and small wind power, etc.

P4 their scope and output: SAM displays modeling result in tabular form, graphs and metrics that shows levelized cost of electricity, operating cost, capital cost and maintenance costs rather than cost it also shows the peak and annual system efficiency, system energy output and hourly system production.

P5 their updatability: Yes, latest version is SAM 2014.1.14, updated on 14 January, 2014

2.8 Solar Design Tool

Solar Design Tool in online tool for designing solar system online, that provide user a comfortable platform to design and configure solar electric power system and panel layout.

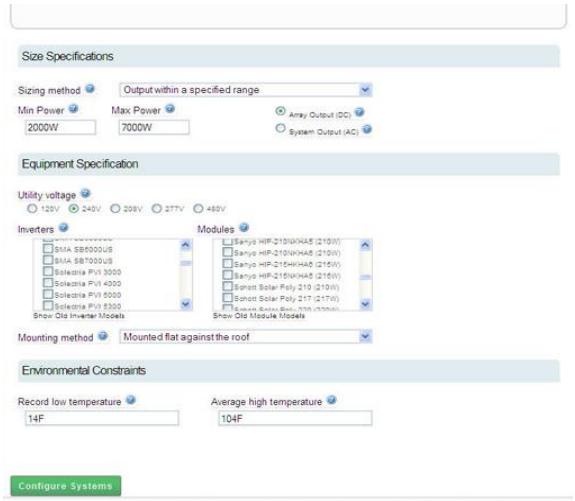

Fig.8 SolarDesignTool window showing selection of size specification and equipment specification

It has many features like string configuration for string and distributed MPPT inverter systems, branch configuration for micro inverter system, automatic optimal panel layout generation and an embedded drawing tool to quickly sketch or modifying installation areas.

*P1 their commercial and educational availability and cost***:** Free version is available for trial but further we have to pay for it. It is available in three mode Lite, Professional and small-medium business, professional is available in $25 per machine for a month validity, $22.67 per machine for quarter and $20 per machine for annual.

P2 their working platform: It is internet based platform can be used on Google Chrome, Firefox 3.5 or above, Internet Explorer 7/8, and Apple Safari. It do not support Internet Explorer 6.

P3 their working capacities: It can be used to generate system designs, string sizing, and system comparison and array layout design

P4 their scope and output: It provides a list of all system output for the supplied inputs and provide output in comparative form is a summary report of the system. The major output in summary report include record of low temperature and average high temperature of installation site, STC DC output, of array, PTC DC output of array, CEC output of array, number, model name sand specification, area of array maximum AC output current and basic schematics of the roof.

P5 their updatability: No, not required

2.9 Environmental System Performance-renewable (ESP-r)

ESP-r is an integrated renewable energy modelling tool for simulation of the visual, acoustic and thermal performance of building and the energy use and gaseous emissions along with associated environmental control system.

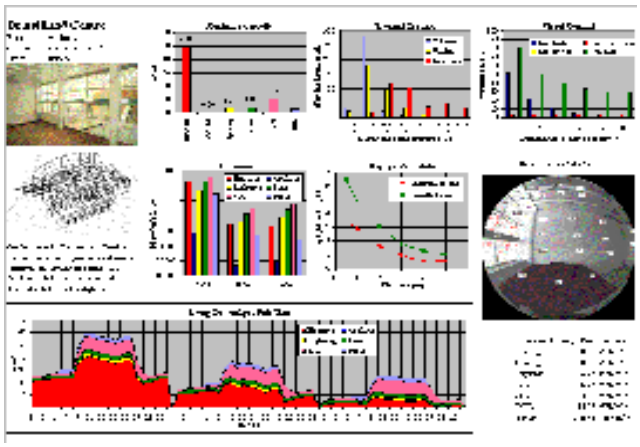

Fig.9 ESP-r window showing annual energy performance

It equipped to model heat, air, moisture and electrical power flows at user determined resolution. It was developed by the University of Strathclyde; it is primarily used in research or as a teaching tool.

P1 their commercial and educational availability and cost: Free of cost available for all users.

P2 their working platform: Windows NT/2000/XP or newer, Linux.

P3 their working capacities: It has state of art standard simulation features; it has powerful capability to simulate many innovative technologies including daylight utilization, natural ventilation, contaminant distribution, combined heat and electrical power generation and photovoltaic exterior of the building, adaptive 3D computational fluid dynamics, multi-gridding in 2D/3D environment and control systems.

P4 their scope and output: It is an interactive tool that provides different views of simulation results, variety of performance analysis and interaction between session between assessment domains. Many tools provided to enable the construction of an integrated performance analysis over a range of relevant criteria as per user choice. Analysis is essentially unrestricted and data can be exported to another analysis and graphics.

P5 their updatability: Yes, latest version is ESP11.11 released on June 29, 2011

2.10 Solar Pro

Solar Pro is sophisticated simulation software for photovoltaic system; it is able to simulate electricity generation under different conditions that is varied by each system, so that it allows system design based on precise data, since the calculated data come out with persuasive and graphical look.

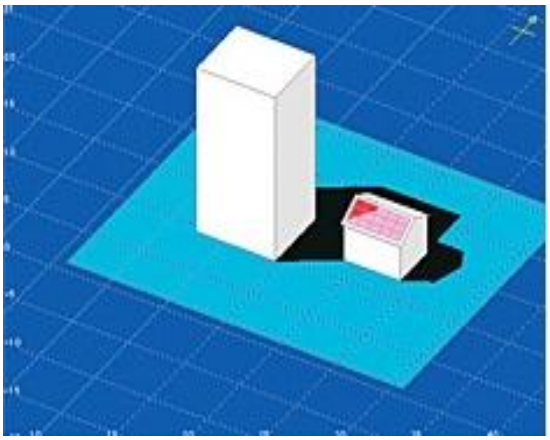

Fig.10 3D shading analysis using Solar Pro

It can be utilized for presentation and education related to photovoltaic system generation.

P1 their commercial and educational availability and cost: Free of cost/ open for all purpose

P2 their working platform: It supports Windows XP/Vista/7 with 32 bit processing.

P3 their working capacities: Solar Pro contains many features basically; it has 3D CAD which is used to simulate shadow influence by the surrounding building and objects, so the user can set optimal setting before the installation of panel. IV cure that is calculated based on module electrical characteristics of each manufactures accurately and quickly.

It also calculate the amount of power generated form the system based on the latitude, longitude and the weather conditions of the installation site, this provide precise simulation results.

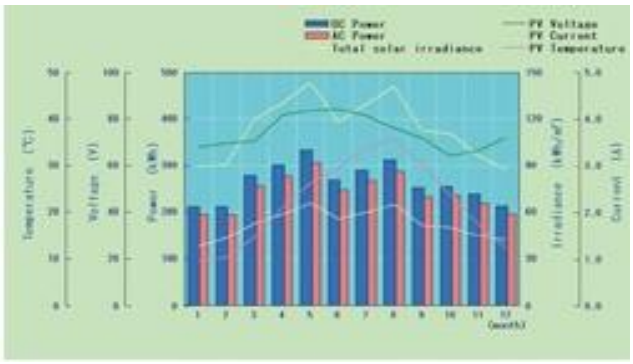

Fig.11 Electrical power output bars in Solar Pro

P4 their scope and output: Solar Pro output in many forms electrical power generation, I-V curve, shadow effect and life cycle analysis.

P5 their updatability: Yes, latest version is Solar Pro Ver. 4.1 and Ver. 4.2 coming soon.

2.11 PhotoVoltaic Design Program-Grid connected system (PV DesignPro-G)

It designed to simulate photovoltaic energy system operation for one year on an hourly basis. The simulation result is based on climate and parameter selected by the user. PV DesignPro is available in three version PV DesignPro-S for standalone systems, PV DesignPro-G for grid connected systems and PV DesignPro-P for water pumping systems.

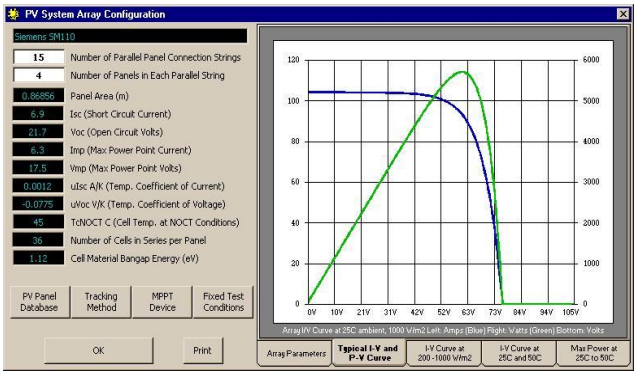

Fig.11 PV DesignPro-G window showing parameter selection and P-V and I-V curve

P1 their commercial and educational availability and cost: Available in package of $249 solar design Studio.

P2 their working platform: It supports window XP / Vista / 7 / 8 / 32&64 bit / Mac OS

*P3 their working capacities***:** PV DesignPro is best suitable to professional as well as for research purpose. The main objective behind the development of this software is that it provide accurate and depth information on likely system power output and load consumption, backup during the system operation as well as financial impact of the installing the proposed system. Six type of panel tracking is incorporated into the program fixed slope and axis, tracking on horizontal north-south axis, tracking on horizontal east-west axis, tracking on north-south axis

parallel to the earth axis, tracking on vertical axis with fixed slope and continuous tracking on two axis. Panel shading information also can be entered into the syste.

P4 their scope and output: Output of PV DesignPro is very user friendlily; it shows solar fraction charts by month, storage states of the charge by month, annual performance of energy produced, necessary backup and state-of-charge. It also provide the detail analysis regarding cash flow of purchased and sold energy, systems cost, cost of backup energy, prices of sold energy, maintenance and replacement cost and estimated life of the system.

P5 their updatability: Yes, latest version 6.0 is released on 19 December, 2010

*2.12 PhotoVoltaic Solar Expert (PV*SOL Expert)*

PV*SOL Expert is solar project analysis and planning tools that is used to represent the real word the shading effect from the surrounding objects, so this software is used to takes shading into analytically as much possible.

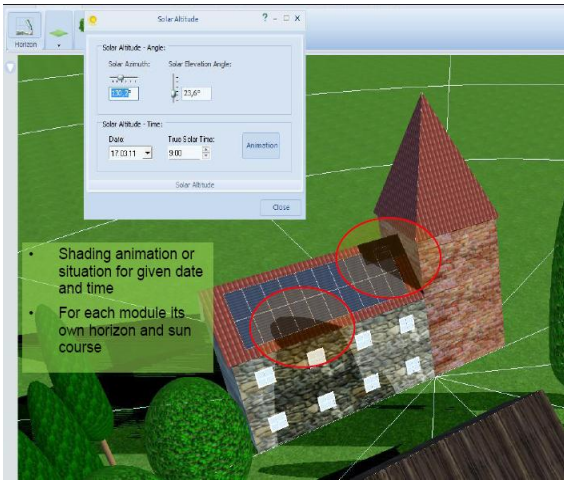

Fig.12 PV*SOL Expert window showing shading animation for given date and time

We can also visualize all roof-integrated or mounted system; even we can calculate shading on the basis of 3D object. It is a multiproduct suite of software for the design, simulation and project financial analysis of the photovoltaic systems ranging from small off-grid to large grid connected system and utility scale.

P1 their commercial and educational availability and cost: Cost for single user Euro 1228.00 PV*SOL Expert Set and Euro 998.00 PV*SOL gridcon.

P2 their working platform: It supports Windows XP/SP3/Vista/7/8 operating system.

P3 their working capacities: The PV*SOL contains two types simulation software PV*SOL expert and PV*SOL gridcon, PV*SOL gridcon contains 3d visualization of PV systems with shade calculation based on 3D shading or object. Optimization can be done by user first select modules and then modules are configured with the inverters. User can optimize the allocation of the module based on the shading position. Then software configures the individual strings.

P4 their scope and output: It provide 3D visualization of yearly radiation reduction for each point of the PV area as well as optimized PV module coverage and the configuration depends on the corresponding to the shading position. It has manual as well as automatic PV module roof coverage and accounts restricted area also. Simulation results intervals 10 minute module yield accounts precise shading ration for each module. Animated 3D visualization can be done of the shade and can be obtained at any time.

P5 their updatability: Yes, PV*SOL 6.0 available for end user.

3. Conclusions

There is an apparent extent of simulation software for simulation, economic evaluation, photovoltaic industry related, analysis and planning, monitoring and control, solar radiation map and online simulation software. All discussed simulation software's are available commercial and educational purpose some are free of charge and for some we need to pay some charge to use them. All these simulation software's are updated, user friendly and experimental validation, these software are designed with different goals in mind, they have some limitation to solve certain problems. The desirable simulation software for manufacturing depends on the purpose of their use, all discussed software used in its specific area of application or specialization. This paper will help end user to select precise software for particular job as simulation, economic evaluation, photovoltaic industry related, analysis and planning, monitoring and control, solar radiation map.

We can see that from above analysis PVsyst is very good software for simulation and analysis, so we are using PVsyst for our analysis.

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