

solar power calculation formula pdf

solar power calculation formula pdf is an essential resource for engineers, solar energy professionals, students, and hobbyists interested in designing, analyzing, and understanding solar power systems. Whether you're planning a residential solar installation, conducting academic research, or simply seeking to deepen your knowledge of solar energy calculations, having a comprehensive PDF document outlining the formulas and their applications is invaluable. This article provides an in-depth overview of the key solar power calculation formulas, their significance, and how to utilize them effectively, all structured to support your learning and practical implementation.

Understanding Solar Power Calculation Basics

Before diving into specific formulas, it's crucial to grasp the fundamental concepts that underpin solar power calculations. These basics serve as the foundation for understanding how to estimate the energy potential of a solar panel system.

Key Concepts in Solar Power Estimation

- **Solar Irradiance:** The power per unit area received from the Sun, typically measured in watts per square meter (W/m^2).
- **Panel Efficiency:** The ratio of electrical power output to solar power input, indicating how effectively a panel converts sunlight into electricity.
- **System Losses:** Factors such as shading, dirt, temperature, and wiring losses that reduce the overall system performance.
- **Peak Sun Hours:** The equivalent number of hours per day when solar irradiance averages 1000 W/m^2 , used to estimate energy production.

Key Solar Power Calculation Formulas

The core of solar energy assessment involves several standardized formulas that help estimate the potential energy output, system size, and performance metrics. Below are the most commonly used formulas, explained in detail.

1. Solar Panel Power Output Calculation

This formula estimates the electrical power output (W) of a solar panel under specific conditions:

$$P = A \times r \times H \times PR$$

Where:

- **P:** Power output (Watts)
- **A:** Area of the solar panel (m²)
- **r:** Solar panel efficiency (decimal form, e.g., 0.15 for 15%)
- **H:** Solar irradiance (peak sun hours) or daily insolation (kWh/m²/day)
- **PR:** System Performance Ratio (accounts for system losses, typically 0.75–0.9)

Application:

- To estimate the daily energy production, multiply the power output by the number of peak sun hours.

2. Energy Production Estimation

To determine the total energy a solar system can generate in a day:

$$E = P \times H$$

Where:

- **E:** Daily energy production (kWh)
- **P:** Power output (kW)
- **H:** Peak sun hours (hours)

Note: For monthly or yearly estimations, sum or integrate the daily values over the desired period.

3. System Size Calculation

To size a solar power system based on energy needs:

$$\text{Size (kW)} = \frac{\text{Daily Energy Requirement (kWh)}}{H \times PR}$$

Steps:

1. Determine your daily energy consumption (kWh).
2. Use local peak sun hours (H) for your location.
3. Adjust for system losses (PR).

4. Estimating Solar Panel Area

To calculate the total area of solar panels needed:

$$A = \frac{P}{r \times H \times PR}$$

Where:

- P: Desired system power (Watts)
- r: Panel efficiency
- H: Peak sun hours
- PR: Performance ratio

Additional Important Formulas and Considerations

Beyond the basic formulas, several other calculations are necessary for comprehensive solar system design and analysis.

1. Adjusting for Temperature Effects

Solar panels are affected by temperature, which impacts efficiency:

$$P_{\text{temp}} = P_{\text{STC}} \times [1 + \gamma \times (T_{\text{cell}} - T_{\text{STC}})]$$

Where:

- **P_{temp}** : Power at operating temperature
- **P_{STC}** : Power at Standard Test Conditions (usually 1000 W/m² and 25°C)
- **γ** : Temperature coefficient (%/°C)
- **T_{cell}** : Cell temperature (°C)
- **T_{STC}** : Standard Test Conditions temperature (25°C)

Note: Cell temperature can be estimated by:

$$T_{\text{cell}} = T_{\text{ambient}} + \frac{\text{NOCT} - 20}{800} \times G_{\text{solar}}$$

Where:

- NOCT: Nominal Operating Cell Temperature (°C)
- G_{solar} : Solar irradiance (W/m²)

2. Levelized Cost of Energy (LCOE)

For economic analysis, LCOE is a key metric:

$$\text{LCOE} = \frac{\text{Total Lifecycle Cost}}{\text{Total Energy Produced}}$$

This helps compare the cost-effectiveness of different solar systems.

Creating a PDF with Solar Power Calculation Formulas

Having a well-organized PDF document that consolidates all relevant formulas is critical for quick reference and precise calculations. Here's how to create or find such a resource:

1. **Gather Content:** Collect all key formulas, their explanations, and application contexts.
2. **Organize Logically:** Structure the document from basic concepts to advanced calculations.
3. **Use Clear Formatting:** Employ headings, subheadings, bullet points, and tables for clarity.
4. **Include Examples:** Provide sample calculations to illustrate each formula.
5. **Incorporate Visuals:** Diagrams, charts, and graphs help in understanding complex relationships.
6. **Convert to PDF:** Use document editors like Word or LaTeX, then export to PDF format for portability.

Many online resources and engineering textbooks provide downloadable PDFs containing these formulas. Always ensure that the source is reputable and up-to-date, especially considering evolving technologies and standards.

Sources for Solar Power Calculation PDFs

- National Renewable Energy Laboratory (NREL): Offers comprehensive guides and PDFs on solar calculations.
- International Renewable Energy Agency (IRENA): Provides technical reports and calculation formulas.
- Academic Textbooks: Engineering and renewable energy textbooks often include downloadable PDF resources.
- Industry Standards and Guidelines: Such as IEC standards, which include formulas and testing procedures.

Conclusion

A well-organized solar power calculation formula pdf serves as a vital tool for accurately designing and analyzing solar energy systems. By understanding and applying the key formulas—ranging from basic power output estimations to more complex temperature and economic considerations—you can optimize system performance and ensure cost-effectiveness. Whether you're a professional engineer, a student, or a solar enthusiast, having access to detailed, reliable PDFs with formulas and examples enhances your ability to make informed decisions in the ever-evolving field of solar energy. Always seek the latest standards and verified resources to stay current with best practices and technological advancements in solar power calculations.

Frequently Asked Questions

What is the basic formula used to calculate solar power generation?

The basic formula is $\text{Power (W)} = \text{Solar Irradiance (W/m}^2\text{)} \times \text{Solar Panel Area (m}^2\text{)} \times \text{Efficiency}$. This helps estimate the energy output based on sunlight and panel specifications.

Where can I find a comprehensive PDF guide on solar power calculation formulas?

You can find detailed PDFs on solar power calculation formulas on industry websites, renewable energy educational platforms, and engineering resource sites like IEEE, ResearchGate, or solar energy associations.

How do I calculate the expected energy output of a solar panel system using a PDF formula?

You can use the formula: $\text{Energy (kWh)} = \text{Solar Irradiance (kWh/m}^2\text{/day)} \times \text{Panel Area (m}^2\text{)} \times \text{System Efficiency} \times \text{Days}$. PDFs often include step-by-step examples for accurate calculations.

What parameters are typically included in a solar power calculation PDF?

Parameters usually include solar irradiance, panel efficiency, system losses, shading factors, tilt and orientation angles, and local weather data.

How accurate are solar power calculation formulas found in PDFs?

The accuracy depends on the quality of input data and assumptions made. PDFs often provide estimates; for precise planning, real-world measurements and site-specific data are recommended.

Can I use a PDF calculator for both residential and commercial solar projects?

Yes, most PDF guides and formulas are adaptable for both residential and commercial systems, with adjustments for system size, shading, and specific site conditions.

Are there online tools that incorporate the formulas from solar power calculation PDFs?

Yes, numerous online calculators and software integrate these formulas, allowing users to input data and get quick estimates based on standard calculation methods from PDFs.

What are the common units used in solar power calculation PDFs?

Common units include watts (W), kilowatt-hours (kWh), square meters (m^2), hours, and irradiance in W/m^2 or $\text{kWh}/\text{m}^2/\text{day}$, depending on the context of the calculation.

Additional Resources

Solar Power Calculation Formula PDF: A Comprehensive Guide to Understanding and Applying Solar Power Calculations

In the rapidly evolving world of renewable energy, solar power calculation formula PDF resources have become invaluable tools for engineers, architects, homeowners, and energy consultants alike. These documents compile essential formulas, step-by-step procedures, and practical examples to help users accurately estimate solar energy potential, system sizing, and financial feasibility. Whether you're designing a new solar installation, evaluating existing systems, or simply seeking to deepen your understanding of solar energy metrics, a well-structured PDF guide can serve as a reliable reference point.

Why a Solar Power Calculation Formula PDF Is Essential

Before diving into the technicalities, it's important to understand why having a dedicated PDF resource is beneficial:

- Consolidated Information: Combines all relevant formulas, constants, and conversion factors in one accessible document.
- Standardized Calculations: Ensures consistency and accuracy in designing or analyzing solar systems.
- Educational Value: Serves as a learning tool for new practitioners or students in renewable energy fields.
- Practical Application: Offers real-world examples, case studies, and step-by-step procedures to facilitate understanding.
- Resource for Certification and Permitting: Many regulatory bodies and certification programs rely on standardized calculation methods documented in PDFs.

Key Components of a Solar Power Calculation Formula PDF

A comprehensive PDF document typically covers several core aspects of solar power calculations, including:

1. Solar Radiation and Irradiance Calculations

Understanding the amount of solar energy received at a location is foundational. The formulas involve:

- Global Solar Radiation: Total solar energy received per unit area over a specific period.
- Average Solar Irradiance: The average power received from the sun, typically expressed in kWh/m²/day.

2. System Sizing and Energy Output Estimation

Calculating the appropriate size of a solar PV system involves:

- Daily Energy Needs: The total energy consumption, often measured in kWh/day.
- System Efficiency Factors: Accounting for losses due to inverter inefficiencies, dirt, shading, and temperature effects.
- Peak Sun Hours (PSH): The equivalent number of hours per day when solar irradiance averages 1,000 W/m².

3. Performance Ratio and Capacity Factor

These metrics evaluate how effectively a system produces energy:

- Performance Ratio (PR): The ratio of actual energy output to the theoretical maximum.
- Capacity Factor (CF): The actual output over a period divided by the maximum possible output if the system operated at full capacity continuously.

4. Economic and Financial Calculations

Estimating financial feasibility involves:

- Levelized Cost of Energy (LCOE): The average cost per kWh over the system's lifetime.
- Return on Investment (ROI): The profitability metric.
- Payback Period: Time it takes for the investment to recoup its initial cost.

Core Solar Power Calculation Formulas

Below are some of the most commonly used formulas found in solar power calculation formula PDF documents, explained in detail.

1. Solar Panel Power Output

Formula:

$$P_{\text{solar}} = A \times G \times r \times \eta$$

Where:

- P_{solar} = Power output (Watts)
- A = Area of the solar panel (m^2)
- G = Solar irradiance (W/m^2)
- r = Panel efficiency (decimal)
- η = System losses factor (decimal; typically 0.75 - 0.9)

Application:

Estimate the potential power output based on panel size, local solar irradiance, and efficiency.

2. Daily Energy Production

Formula:

$$E_{\text{daily}} = P_{\text{solar}} \times H_{\text{sun}}$$

Where:

- E_{daily} = Daily energy production (kWh)
- P_{solar} = Power output (kW)
- H_{sun} = Peak Sun Hours per day

Note: Peak Sun Hours (PSH) are determined based on local solar data and represent the equivalent hours of full solar irradiance.

3. System Size Calculation

To determine the required system capacity:

$$P_{\text{system}} = \frac{E_{\text{daily_needs}}}{H_{\text{sun}} \times \eta_{\text{system}}}$$

Where:

- $E_{\text{daily_needs}}$ = Daily energy consumption (kWh)
- H_{sun} = Peak Sun Hours
- η_{system} = Total system efficiency (including inverter, losses, etc.)

4. Financial Metrics

Levelized Cost of Energy (LCOE):

$$LCOE = \frac{\text{Total System Cost}}{\text{Total Energy Generated over System Lifetime}}$$

Step-by-Step Guide to Using the Formulas

Step 1: Gather Local Solar Data

- Use solar maps, satellite data, or meteorological stations to find average solar irradiance and Peak Sun Hours.
- Obtain local weather information to adjust for seasonal variations.

Step 2: Determine Energy Needs

- Calculate or reference your household or facility's average daily energy consumption.
- Adjust for future expansion or efficiency improvements if necessary.

Step 3: Select Appropriate Equipment

- Choose panels with known efficiency ratings.
- Determine the required panel area based on the power output needed.

Step 4: Calculate System Size

- Use the formulas provided to estimate the capacity needed to meet your energy goals.
- Account for system losses by applying the efficiency factor.

Step 5: Estimate Energy Production

- Calculate expected daily, monthly, and annual energy output.
- Use performance ratio to refine estimates.

Step 6: Perform Financial Analysis

- Calculate the LCOE.
- Estimate ROI and payback period based on local electricity rates and incentives.

Additional Considerations Covered in a PDF Guide

A well-structured solar power calculation formula PDF also discusses:

- Tilt and Azimuth Optimization: How orientation affects solar receipt.
- Shading Analysis: Impact of shading on system performance.
- Temperature Effects: How temperature influences panel efficiency.
- Degradation Rates: Expected decline in panel output over time.
- Regulatory Standards: Local codes and standards for solar installations.

Practical Tips for Using Solar Power Calculation PDFs

- Always Use Updated Data: Solar radiation data can vary; ensure your source is current.
- Double-Check Units: Consistency in units (e.g., kW vs. W, hours vs. seconds) prevents errors.
- Include Safety Margins: Slightly oversize your system to compensate for unexpected losses.
- Consult Multiple Sources: Cross-reference formulas and data for accuracy.
- Leverage Software Tools: Many PDFs include Excel templates or software recommendations for easier calculations.

Conclusion

A solar power calculation formula PDF is an essential resource for anyone involved in designing, analyzing, or investing in solar energy systems. It consolidates vital formulas, provides step-by-step instructions, and offers practical insights to ensure accurate and reliable system sizing and performance estimation. By mastering these formulas and methodologies, stakeholders can optimize their solar investments, maximize energy production, and contribute effectively to the global transition toward renewable energy.

Whether you are a beginner or an experienced professional, having a well-structured PDF guide at your fingertips can streamline your workflow, improve accuracy, and support informed decision-making in the pursuit of sustainable energy solutions.

[Solar Power Calculation Formula Pdf](#)

solar power calculation formula pdf: *Sun Tracking and Solar Renewable Energy Harvesting*
Gerro Prinsloo, Robert Dobson, 2015-11-02 Free to download eBook on Practical Solar Tracking Design, Solar Tracking, Sun Tracking, Sun Tracker, Solar Tracker, Follow Sun, Sun Position calculation (Azimuth, Elevation, Zenith), Sun following, Sunrise, Sunset, Moon-phase, Moonrise, Moonset calculators. In harnessing power from the sun through a solar tracker or solar tracking system, renewable energy system developers require automatic solar tracking software and solar position algorithms. On-axis sun tracking system such as the altitude-azimuth dual axis or multi-axis solar tracker systems use a sun tracking algorithm or ray tracing sensors or software to ensure the sun's passage through the sky is traced with high precision in automated solar tracker applications, right through summer solstice, solar equinox and winter solstice. Eco Friendly and Environmentally Sustainable Micro Combined Solar Heat and Power (m-CHP, m-CCHP, m-CHCP) with Microgrid Storage and Layered Smartgrid Control towards Supplying Off-Grid Rural Villages in developing BRICS countries such as Africa, India, China and Brazil. Off-grid rural villages and isolated islands areas require mCHP and trigeneration solar power plants and associated isolated smart microgrid solutions to serve the community energy needs. This article describes the development progress for such a system, also referred to as solar polygeneration. The system includes a sun tracker mechanism wherein a parabolic dish or lenses are guided by a light sensitive mechanism in a way that the solar receiver is always at right angle to the solar radiation. Solar thermal energy is then either converted into electrical energy through a free piston Stirling, or stored in a thermal storage container. The project includes the thermodynamic modeling of the plant in Matlab Simulink as well

as the development of an intelligent control approach that includes smart microgrid distribution and optimization. The book includes aspects in the simulation and optimization of stand-alone hybrid renewable energy systems and co-generation in isolated or islanded microgrids. It focusses on the stepwise development of a hybrid solar driven micro combined cooling heating and power (mCCHP) compact trigeneration polygeneration and thermal energy storage (TES) system with intelligent weather prediction, weak-ahead scheduling (time horizon), and look-ahead dispatch on integrated smart microgrid distribution principles. The solar harvesting and solar thermodynamic system includes an automatic sun tracking platform based on a PLC controlled mechatronic sun tracking system that follows the sun progressing across the sky. An intelligent energy management and adaptive learning control optimization approach is proposed for autonomous off-grid remote power applications, both for thermodynamic optimization and smart micro-grid optimization for distributed energy resources (DER). The correct resolution of this load-following multi objective optimization problem is a complex task because of the high number and multi-dimensional variables, the cross-correlation and interdependency between the energy streams as well as the non-linearity in the performance of some of the system components. Exergy-based control approaches for smartgrid topologies are considered in terms of the intelligence behind the safe and reliable operation of a microgrid in an automated system that can manage energy flow in electrical as well as thermal energy systems. The standalone micro-grid solution would be suitable for a rural village, intelligent building, district energy system, campus power, shopping mall centre, isolated network, eco estate or remote island application setting where self-generation and decentralized energy system concepts play a role. Discrete digital simulation models for the thermodynamic and active demand side management systems with digital smartgrid control unit to optimize the system energy management is currently under development. Parametric simulation models for this trigeneration system (polygeneration, poligeneration, quadgeneration) are developed on the Matlab Simulink and TrnSys platforms. In terms of model predictive coding strategies, the automation controller will perform multi-objective cost optimization for energy management on a microgrid level by managing the generation and storage of electrical, heat and cooling energies in layers. Each layer has its own set of smart microgrid priorities associated with user demand side cycle predictions. Mixed Integer Linear Programming and Neural network algorithms are being modeled to perform Multi Objective Control optimization as potential optimization and adaptive learning techniques.

solar power calculation formula pdf: Introduction to Renewable Energy Vaughn C.

Nelson, Kenneth L. Starcher, 2015-11-18 Introduction to Renewable Energy, Second Edition covers the fundamentals of renewable energy and serves as a resource to undergraduates in renewable energy courses, non-specialists within the energy industries, or anyone working to support the successful implementation of renewable energy. The second edition discusses developments that have occurred

solar power calculation formula pdf: Practical Solar Tracking Automatic Solar Tracking

Sun Tracking Автоматическое удержание Солнечная слежения ВС Gerro Prinsloo, Robert Dobson, 2015-11-01 This book details Practical Solar Energy Harvesting, Automatic Solar-Tracking, Sun-Tracking-Systems, Solar-Trackers and Sun Tracker Systems using motorized automatic positioning concepts and control principles. An intelligent automatic solar tracker is a device that orients a payload toward the sun. Such programmable computer based solar tracking device includes principles of solar tracking, solar tracking systems, as well as microcontroller, microprocessor and/or PC based solar tracking control to orientate solar reflectors, solar lenses, photovoltaic panels or other optical configurations towards the sun. Motorized space frames and kinematic systems ensure motion dynamics and employ drive technology and gearing principles to steer optical configurations such as mangin, parabolic, conic, or cassegrain solar energy collectors to face the sun and follow the sun movement contour continuously. In general, the book may benefit solar research and solar energy applications in countries such as Africa, Mediterranean, Italy, Spain, Greece, USA, Mexico, South America, Brazilia, Argentina, Chili, India, Malaysia, Middle East, UAE, Russia, Japan and China. This book on practical automatic Solar-Tracking Sun-Tracking is in .PDF

format and can easily be converted to the .EPUB .MOBI .AZW .ePub .FB2 .LIT .LRF .MOBI .PDB .PDF .TCR formats for smartphones and Kindle by using the ebook.online-convert.com facility. The content of the book is also applicable to communication antenna satellite tracking and moon tracking algorithm source code for which links to free download links are provided. In harnessing power from the sun through a solar tracker or practical solar tracking system, renewable energy control automation systems require automatic solar tracking software and solar position algorithms to accomplish dynamic motion control with control automation architecture, circuit boards and hardware. On-axis sun tracking system such as the altitude-azimuth dual axis or multi-axis solar tracker systems use a sun tracking algorithm or ray tracing sensors or software to ensure the sun's passage through the sky is traced with high precision in automated solar tracker applications, right through summer solstice, solar equinox and winter solstice. A high precision sun position calculator or sun position algorithm is this an important step in the design and construction of an automatic solar tracking system. From sun tracing software perspective, the sonnet Tracing The Sun has a literal meaning. Within the context of sun track and trace, this book explains that the sun's daily path across the sky is directed by relatively simple principles, and if grasped/understood, then it is relatively easy to trace the sun with sun following software. Sun position computer software for tracing the sun are available as open source code, sources that is listed in this book. Ironically there was even a system called sun chaser, said to have been a solar positioner system known for chasing the sun throughout the day. Using solar equations in an electronic circuit for automatic solar tracking is quite simple, even if you are a novice, but mathematical solar equations are over complicated by academic experts and professors in text-books, journal articles and internet websites. In terms of solar hobbies, scholars, students and Hobbyist's looking at solar tracking electronics or PC programs for solar tracking are usually overcome by the sheer volume of scientific material and internet resources, which leaves many developers in frustration when search for simple experimental solar tracking source-code for their on-axis sun-tracking systems. This booklet will simplify the search for the mystical sun tracking formulas for your sun tracker innovation and help you develop your own autonomous solar tracking controller. By directing the solar collector directly into the sun, a solar harvesting means or device can harness sunlight or thermal heat. This is achieved with the help of sun angle formulas, solar angle formulas or solar tracking procedures for the calculation of sun's position in the sky. Automatic sun tracking system software includes algorithms for solar altitude azimuth angle calculations required in following the sun across the sky. In using the longitude, latitude GPS coordinates of the solar tracker location, these sun tracking software tools supports precision solar tracking by determining the solar altitude-azimuth coordinates for the sun trajectory in altitude-azimuth tracking at the tracker location, using certain sun angle formulas in sun vector calculations. Instead of follow the sun software, a sun tracking sensor such as a sun sensor or webcam or video camera with vision based sun following image processing software can also be used to determine the position of the sun optically. Such optical feedback devices are often used in solar panel tracking systems and dish tracking systems. Dynamic sun tracing is also used in solar surveying, DNI analyser and sun surveying systems that build solar infographics maps with solar radiance, irradiance and DNI models for GIS (geographical information system). In this way geospatial methods on solar/environment interaction makes use use of geospatial technologies (GIS, Remote Sensing, and Cartography). Climatic data and weather station or weather center data, as well as queries from sky servers and solar resource database systems (i.e. on DB2, Sybase, Oracle, SQL, MySQL) may also be associated with solar GIS maps. In such solar resource modelling systems, a pyranometer or solarimeter is normally used in addition to measure direct and indirect, scattered, dispersed, reflective radiation for a particular geographical location. Sunlight analysis is important in flash photography where photographic lighting are important for photographers. GIS systems are used by architects who add sun shadow applets to study architectural shading or sun shadow analysis, solar flux calculations, optical modelling or to perform weather modelling. Such systems often employ a computer operated telescope type mechanism with ray tracing program software as a solar navigator or sun tracer that determines the solar position

and intensity. The purpose of this booklet is to assist developers to track and trace suitable source-code and solar tracking algorithms for their application, whether a hobbyist, scientist, technician or engineer. Many open-source sun following and tracking algorithms and source-code for solar tracking programs and modules are freely available to download on the internet today. Certain proprietary solar tracker kits and solar tracking controllers include a software development kit SDK for its application programming interface API attributes (Pebble). Widget libraries, widget toolkits, GUI toolkit and UX libraries with graphical control elements are also available to construct the graphical user interface (GUI) for your solar tracking or solar power monitoring program. The solar library used by solar position calculators, solar simulation software and solar contour calculators include machine program code for the solar hardware controller which are software programmed into Micro-controllers, Programmable Logic Controllers PLC, programmable gate arrays, Arduino processor or PIC processor. PC based solar tracking is also high in demand using C++, Visual Basic VB, as well as MS Windows, Linux and Apple Mac based operating systems for sun path tables on Matlab, Excel. Some books and internet webpages use other terms, such as: sun angle calculator, sun position calculator or solar angle calculator. As said, such software code calculate the solar azimuth angle, solar altitude angle, solar elevation angle or the solar Zenith angle (Zenith solar angle is simply referenced from vertical plane, the mirror of the elevation angle measured from the horizontal or ground plane level). Similar software code is also used in solar calculator apps or the solar power calculator apps for IOS and Android smartphone devices. Most of these smartphone solar mobile apps show the sun path and sun-angles for any location and date over a 24 hour period. Some smartphones include augmented reality features in which you can physically see and look at the solar path through your cell phone camera or mobile phone camera at your phone's specific GPS location. In the computer programming and digital signal processing (DSP) environment, (free/open source) program code are available for VB, .Net, Delphi, Python, C, C+, C++, PHP, Swift, ADM, F, Flash, Basic, QBasic, GBasic, KBasic, SIMPL language, Squirrel, Solaris, Assembly language on operating systems such as MS Windows, Apple Mac, DOS or Linux OS. Software algorithms predicting position of the sun in the sky are commonly available as graphical programming platforms such as Matlab (Mathworks), Simulink models, Java applets, TRNSYS simulations, Scada system apps, Labview module, Beckhoff TwinCAT (Visual Studio), Siemens SPA, mobile and iphone apps, Android or iOS tablet apps, and so forth. At the same time, PLC software code for a range of sun tracking automation technology can follow the profile of sun in sky for Siemens, HP, Panasonic, ABB, Allan Bradley, OMRON, SEW, Festo, Beckhoff, Rockwell, Schneider, Endress Hauser, Fuji electric, Honeywell, Fuchs, Yokonawa, or Muthibishi platforms. Sun path projection software are also available for a range of modular IPC embedded PC motherboards, Industrial PC, PLC (Programmable Logic Controller) and PAC (Programmable Automation Controller) such as the Siemens S7-1200 or Siemens Logo, Beckhoff IPC or CX series, OMRON PLC, Ercam PLC, AC500plc ABB, National Instruments NI PXI or NI cRIO, PIC processor, Intel 8051/8085, IBM (Cell, Power, Brain or Truenorth series), FPGA (Xilinx Altera Nios), Intel, Xeon, Atmel megaAVR, MPU, Maple, Teensy, MSP, XMOS, Xbee, ARM, Raspberry Pi, Eagle, Arduino or Arduino AtMega microcontroller, with servo motor, stepper motor, direct current DC pulse width modulation PWM (current driver) or alternating current AC SPS or IPC variable frequency drives VFD motor drives (also termed adjustable-frequency drive, variable-speed drive, AC drive, micro drive or inverter drive) for electrical, mechatronic, pneumatic, or hydraulic solar tracking actuators. The above motion control and robot control systems include analogue or digital interfacing ports on the processors to allow for tracker angle orientation feedback control through one or a combination of angle sensor or angle encoder, shaft encoder, precision encoder, optical encoder, magnetic encoder, direction encoder, rotational encoder, chip encoder, tilt sensor, inclination sensor, or pitch sensor. Note that the tracker's elevation or zenith axis angle may measured using an altitude angle-, declination angle-, inclination angle-, pitch angle-, or vertical angle-, zenith angle- sensor or inclinometer. Similarly the tracker's azimuth axis angle be measured with a azimuth angle-, horizontal angle-, or roll angle-sensor. Chip integrated accelerometer magnetometer gyroscope type angle sensors can also be used

to calculate displacement. Other options include the use of thermal imaging systems such as a Fluke thermal imager, or robotic or vision based solar tracker systems that employ face tracking, head tracking, hand tracking, eye tracking and car tracking principles in solar tracking. With unattended decentralised rural, island, isolated, or autonomous off-grid power installations, remote control, monitoring, data acquisition, digital datalogging and online measurement and verification equipment becomes crucial. It assists the operator with supervisory control to monitor the efficiency of remote renewable energy resources and systems and provide valuable web-based feedback in terms of CO₂ and clean development mechanism (CDM) reporting. A power quality analyser for diagnostics through internet, WiFi and cellular mobile links is most valuable in frontline troubleshooting and predictive maintenance, where quick diagnostic analysis is required to detect and prevent power quality issues. Solar tracker applications cover a wide spectrum of solar applications and solar assisted application, including concentrated solar power generation, solar desalination, solar water purification, solar steam generation, solar electricity generation, solar industrial process heat, solar thermal heat storage, solar food dryers, solar water pumping, hydrogen production from methane or producing hydrogen and oxygen from water (HHO) through electrolysis. Many patented or non-patented solar apparatus include tracking in solar apparatus for solar electric generator, solar desalinator, solar steam engine, solar ice maker, solar water purifier, solar cooling, solar refrigeration, USB solar charger, solar phone charging, portable solar charging tracker, solar coffee brewing, solar cooking or solar drying means. Your project may be the next breakthrough or patent, but your invention is held back by frustration in search for the sun tracker you require for your solar powered appliance, solar generator, solar tracker robot, solar freezer, solar cooker, solar drier, solar pump, solar freezer, or solar dryer project. Whether your solar electronic circuit diagram include a simplified solar controller design in a solar electricity project, solar power kit, solar hobby kit, solar steam generator, solar hot water system, solar ice maker, solar desalinator, hobbyist solar panels, hobby robot, or if you are developing professional or hobby electronics for a solar utility or micro scale solar powerplant for your own solar farm or solar farming, this publication may help accelerate the development of your solar tracking innovation. Lately, solar polygeneration, solar trigeneration (solar triple generation), and solar quad generation (adding delivery of steam, liquid/gaseous fuel, or capture food-grade CO₂) systems have need for automatic solar tracking. These systems are known for significant efficiency increases in energy yield as a result of the integration and re-use of waste or residual heat and are suitable for compact packaged micro solar powerplants that could be manufactured and transported in kit-form and operate on a plug-and play basis. Typical hybrid solar power systems include compact or packaged solar micro combined heat and power (CHP or mCHP) or solar micro combined, cooling, heating and power (CCHP, CHPC, mCCHP, or mCHPC) systems used in distributed power generation. These systems are often combined in concentrated solar CSP and CPV smart microgrid configurations for off-grid rural, island or isolated microgrid, minigrid and distributed power renewable energy systems. Solar tracking algorithms are also used in modelling of trigeneration systems using Matlab Simulink (Modelica or TRNSYS) platform as well as in automation and control of renewable energy systems through intelligent parsing, multi-objective, adaptive learning control and control optimization strategies. Solar tracking algorithms also find application in developing solar models for country or location specific solar studies, for example in terms of measuring or analysis of the fluctuations of the solar radiation (i.e. direct and diffuse radiation) in a particular area. Solar DNI, solar irradiance and atmospheric information and models can thus be integrated into a solar map, solar atlas or geographical information systems (GIS). Such models allows for defining local parameters for specific regions that may be valuable in terms of the evaluation of different solar in photovoltaic or CSP systems on simulation and synthesis platforms such as Matlab and Simulink or in linear or multi-objective optimization algorithm platforms such as COMPOSE, EnergyPLAN or DER-CAM. A dual-axis solar tracker and single-axis solar tracker may use a sun tracker program or sun tracker algorithm to position a solar dish, solar panel array, heliostat array, PV panel, solar antenna or infrared solar antenna. A self-tracking solar concentrator performs automatic solar tracking by computing the solar vector. Solar position

algorithms (TwinCAT, SPA, or PSA Algorithms) use an astronomical algorithm to calculate the position of the sun. It uses astronomical software algorithms and equations for solar tracking in the calculation of sun's position in the sky for each location on the earth at any time of day. Like an optical solar telescope, the solar position algorithm pin-points the solar reflector at the sun and locks onto the sun's position to track the sun across the sky as the sun progresses throughout the day. Optical sensors such as photodiodes, light-dependant-resistors (LDR) or photoresistors are used as optical accuracy feedback devices. Lately we also included a section in the book (with links to microprocessor code) on how the PixArt Wii infrared camera in the Wii remote or Wiimote may be used in infrared solar tracking applications. In order to harvest free energy from the sun, some automatic solar positioning systems use an optical means to direct the solar tracking device. These solar tracking strategies use optical tracking techniques, such as a sun sensor means, to direct sun rays onto a silicon or CMOS substrate to determine the X and Y coordinates of the sun's position. In a solar mems sun-sensor device, incident sunlight enters the sun sensor through a small pin-hole in a mask plate where light is exposed to a silicon substrate. In a web-camera or camera image processing sun tracking and sun following means, object tracking software performs multi object tracking or moving object tracking methods. In an solar object tracking technique, image processing software performs mathematical processing to box the outline of the apparent solar disc or sun blob within the captured image frame, while sun-localization is performed with an edge detection algorithm to determine the solar vector coordinates. An automated positioning system help maximize the yields of solar power plants through solar tracking control to harness sun's energy. In such renewable energy systems, the solar panel positioning system uses a sun tracking techniques and a solar angle calculator in positioning PV panels in photovoltaic systems and concentrated photovoltaic CPV systems. Automatic on-axis solar tracking in a PV solar tracking system can be dual-axis sun tracking or single-axis sun solar tracking. It is known that a motorized positioning system in a photovoltaic panel tracker increase energy yield and ensures increased power output, even in a single axis solar tracking configuration. Other applications such as robotic solar tracker or robotic solar tracking system uses robotica with artificial intelligence in the control optimization of energy yield in solar harvesting through a robotic tracking system. Automatic positioning systems in solar tracking designs are also used in other free energy generators, such as concentrated solar thermal power CSP and dish Stirling systems. The sun tracking device in a solar collector in a solar concentrator or solar collector Such a performs on-axis solar tracking, a dual axis solar tracker assists to harness energy from the sun through an optical solar collector, which can be a parabolic mirror, parabolic reflector, Fresnel lens or mirror array/matrix. A parabolic dish or reflector is dynamically steered using a transmission system or solar tracking slew drive mean. In steering the dish to face the sun, the power dish actuator and actuation means in a parabolic dish system optically focusses the sun's energy on the focal point of a parabolic dish or solar concentrating means. A Stirling engine, solar heat pipe, thermosyphin, solar phase change material PCM receiver, or a fibre optic sunlight receiver means is located at the focal point of the solar concentrator. The dish Stirling engine configuration is referred to as a dish Stirling system or Stirling power generation system. Hybrid solar power systems (used in combination with biogas, biofuel, petrol, ethanol, diesel, natural gas or PNG) use a combination of power sources to harness and store solar energy in a storage medium. Any multitude of energy sources can be combined through the use of controllers and the energy stored in batteries, phase change material, thermal heat storage, and in cogeneration form converted to the required power using thermodynamic cycles (organic Rankin, Brayton cycle, micro turbine, Stirling) with an inverter and charge controller. В этой книге подробно Автоматическая Solar-Tracking, BC-Tracking-Systems, Solar-трекеры и BC Tracker Systems. Интеллектуальный автоматический солнечной слежения является устройством, которое ориентирует полезную нагрузку к солнцу. Такое программируемый компьютер на основе солнечной устройство слежения включает принципы солнечной слежения, солнечных систем слежения, а также микроконтроллер, микропроцессор и / или ПК на базе управления солнечной отслеживания ориентироваться солнечных отражателей, солнечные линзы,

listed in this book. The book also describes the use of satellite tracking software and mechanisms in solar tracking applications. Ironically there was even a system called sun chaser, said to have been a solar positioner system known for chasing the sun throughout the day. Using solar equations in an electronic circuit for automatic solar tracking is quite simple, even if you are a novice, but mathematical solar equations are over complicated by academic experts and professors in text-books, journal articles and internet websites. In terms of solar hobbies, scholars, students and Hobbyist's looking at solar tracking electronics or PC programs for solar tracking are usually overcome by the sheer volume of scientific material and internet resources, which leaves many developers in frustration when search for simple experimental solar tracking source-code for their on-axis sun-tracking systems. This booklet will simplify the search for the mystical sun tracking formulas for your sun tracker innovation and help you develop your own autonomous solar tracking controller. By directing the solar collector directly into the sun, a solar harvesting means or device can harness sunlight or thermal heat. This is achieved with the help of sun angle formulas, solar angle formulas or solar tracking procedures for the calculation of sun's position in the sky. Automatic sun tracking system software includes algorithms for solar altitude azimuth angle calculations required in following the sun across the sky. In using the longitude, latitude GPS coordinates of the solar tracker location, these sun tracking software tools supports precision solar tracking by determining the solar altitude-azimuth coordinates for the sun trajectory in altitude-azimuth tracking at the tracker location, using certain sun angle formulas in sun vector calculations. Instead of follow the sun software, a sun tracking sensor such as a sun sensor or webcam or video camera with vision based sun following image processing software can also be used to determine the position of the sun optically. Such optical feedback devices are often used in solar panel tracking systems and dish tracking systems. Dynamic sun tracing is also used in solar surveying, DNI analyser and sun surveying systems that build solar infographics maps with solar radiance, irradiance and DNI models for GIS (geographical information system). In this way geospatial methods on solar/environment interaction makes use use of geospatial technologies (GIS, Remote Sensing, and Cartography). Climatic data and weather station or weather center data, as well as queries from sky servers and solar resource database systems (i.e. on DB2, Sybase, Oracle, SQL, MySQL) may also be associated with solar GIS maps. In such solar resource modelling systems, a pyranometer or solarimeter is normally used in addition to measure direct and indirect, scattered, dispersed, reflective radiation for a particular geographical location. Sunlight analysis is important in flash photography where photographic lighting are important for photographers. GIS systems are used by architects who add sun shadow applets to study architectural shading or sun shadow analysis, solar flux calculations, optical modelling or to perform weather modelling. Such systems often employ a computer operated telescope type mechanism with ray tracing program software as a solar navigator or sun tracer that determines the solar position and intensity. The purpose of this booklet is to assist developers to track and trace suitable source-code and solar tracking algorithms for their application, whether a hobbyist, scientist, technician or engineer. Many open-source sun following and tracking algorithms and source-code for solar tracking programs and modules are freely available to download on the internet today. Certain proprietary solar tracker kits and solar tracking controllers include a software development kit SDK for its application programming interface API attributes (Pebble). Widget libraries, widget toolkits, GUI toolkit and UX libraries with graphical control elements are also available to construct the graphical user interface (GUI) for your solar tracking or solar power monitoring program. The solar library used by solar position calculators, solar simulation software and solar contour calculators include machine program code for the solar hardware controller which are software programmed into Micro-controllers, Programmable Logic Controllers PLC, programmable gate arrays, Arduino processor or PIC processor. PC based solar tracking is also high in demand using C++, Visual Basic VB, as well as MS Windows, Linux and Apple Mac based operating systems for sun path tables on Matlab, Excel. Some books and internet webpages use other terms, such as: sun angle calculator, sun position calculator or solar angle calculator. As said, such software code calculate the solar azimuth angle, solar

altitude angle, solar elevation angle or the solar Zenith angle (Zenith solar angle is simply referenced from vertical plane, the mirror of the elevation angle measured from the horizontal or ground plane level). Similar software code is also used in solar calculator apps or the solar power calculator apps for IOS and Android smartphone devices. Most of these smartphone solar mobile apps show the sun path and sun-angles for any location and date over a 24 hour period. Some smartphones include augmented reality features in which you can physically see and look at the solar path through your cell phone camera or mobile phone camera at your phone's specific GPS location. In the computer programming and digital signal processing (DSP) environment, (free/open source) program code are available for VB, .Net, Delphi, Python, C, C+, C++, PHP, Swift, ADM, F, Flash, Basic, QBasic, GBasic, KBasic, SIMPL language, Squirrel, Solaris, Assembly language on operating systems such as MS Windows, Apple Mac, DOS or Linux OS. Software algorithms predicting position of the sun in the sky are commonly available as graphical programming platforms such as Matlab (Mathworks), Simulink models, Java applets, TRNSYS simulations, Scada system apps, Labview module, Beckhoff TwinCAT (Visual Studio), Siemens SPA, mobile and iphone apps, Android or iOS tablet apps, and so forth. At the same time, PLC software code for a range of sun tracking automation technology can follow the profile of sun in sky for Siemens, HP, Panasonic, ABB, Allan Bradley, OMRON, SEW, Festo, Beckhoff, Rockwell, Schneider, Endress Hauser, Fudji electric. Honeywell, Fuchs, Yokonawa, or Muthibishi platforms. Sun path projection software are also available for a range of modular IPC embedded PC motherboards, Industrial PC, PLC (Programmable Logic Controller) and PAC (Programmable Automation Controller) such as the Siemens S7-1200 or Siemens Logo, Beckhoff IPC or CX series, OMRON PLC, Ercam PLC, AC500plc ABB, National Instruments NI PXI or NI cRIO, PIC processor, Intel 8051/8085, IBM (Cell, Power, Brain or Truenorth series), FPGA (Xilinx Altera Nios), Intel, Xeon, Atmel megaAVR, MPU, Maple, Teensy, MSP, XMOX, Xbee, ARM, Raspberry Pi, Eagle, Arduino or Arduino AtMega microcontroller, with servo motor, stepper motor, direct current DC pulse width modulation PWM (current driver) or alternating current AC SPS or IPC variable frequency drives VFD motor drives (also termed adjustable-frequency drive, variable-speed drive, AC drive, micro drive or inverter drive) for electrical, mechatronic, pneumatic, or hydraulic solar tracking actuators. The above motion control and robot control systems include analogue or digital interfacing ports on the processors to allow for tracker angle orientation feedback control through one or a combination of angle sensor or angle encoder, shaft encoder, precision encoder, optical encoder, magnetic encoder, direction encoder, rotational encoder, chip encoder, tilt sensor, inclination sensor, or pitch sensor. Note that the tracker's elevation or zenith axis angle may measured using an altitude angle-, declination angle-, inclination angle-, pitch angle-, or vertical angle-, zenith angle- sensor or inclinometer. Similarly the tracker's azimuth axis angle be measured with a azimuth angle-, horizontal angle-, or roll angle-sensor. Chip integrated accelerometer magnetometer gyroscope type angle sensors can also be used to calculate displacement. Other options include the use of thermal imaging systems such as a Fluke thermal imager, or robotic or vision based solar tracker systems that employ face tracking, head tracking, hand tracking, eye tracking and car tracking principles in solar tracking. With unattended decentralised rural, island, isolated, or autonomous off-grid power installations, remote control, monitoring, data acquisition, digital datalogging and online measurement and verification equipment becomes crucial. It assists the operator with supervisory control to monitor the efficiency of remote renewable energy resources and systems and provide valuable web-based feedback in terms of CO2 and clean development mechanism (CDM) reporting. A power quality analyser for diagnostics through internet, WiFi and cellular mobile links is most valuable in frontline troubleshooting and predictive maintenance, where quick diagnostic analysis is required to detect and prevent power quality issues. Solar tracker applications cover a wide spectrum of solar applications and solar assisted application, including concentrated solar power generation, solar desalination, solar water purification, solar steam generation, solar electricity generation, solar industrial process heat, solar thermal heat storage, solar food dryers, solar water pumping, hydrogen production from methane or producing hydrogen and oxygen from water (HHO) through electrolysis. Many patented or

non-patented solar apparatus include tracking in solar apparatus for solar electric generator, solar desalinator, solar steam engine, solar ice maker, solar water purifier, solar cooling, solar refrigeration, USB solar charger, solar phone charging, portable solar charging tracker, solar coffee brewing, solar cooking or solar drying means. Your project may be the next breakthrough or patent, but your invention is held back by frustration in search for the sun tracker you require for your solar powered appliance, solar generator, solar tracker robot, solar freezer, solar cooker, solar drier, solar pump, solar freezer, or solar dryer project. Whether your solar electronic circuit diagram include a simplified solar controller design in a solar electricity project, solar power kit, solar hobby kit, solar steam generator, solar hot water system, solar ice maker, solar desalinator, hobbyist solar panels, hobby robot, or if you are developing professional or hobby electronics for a solar utility or micro scale solar powerplant for your own solar farm or solar farming, this publication may help accelerate the development of your solar tracking innovation. Lately, solar polygeneration, solar trigeneration (solar triple generation), and solar quad generation (adding delivery of steam, liquid/gaseous fuel, or capture food-grade CO₂) systems have need for automatic solar tracking. These systems are known for significant efficiency increases in energy yield as a result of the integration and re-use of waste or residual heat and are suitable for compact packaged micro solar powerplants that could be manufactured and transported in kit-form and operate on a plug-and play basis. Typical hybrid solar power systems include compact or packaged solar micro combined heat and power (CHP or mCHP) or solar micro combined, cooling, heating and power (CCHP, CHPC, mCCHP, or mCHPC) systems used in distributed power generation. These systems are often combined in concentrated solar CSP and CPV smart microgrid configurations for off-grid rural, island or isolated microgrid, minigrid and distributed power renewable energy systems. 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