Growatt Monitor

1. Solar System Performance and Forecasting Calculation Guide

Growatt Devices Monitoring System Documentation

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2. Solar System Performance and Forecasting Calculation Guide

2.1 Table of Contents

2.2 Introduction

This document outlines the key formulas and methodologies used to calculate system performance and forecast production in solar photovoltaic (PV) systems. These calculations are essential for planning, monitoring, and optimizing solar installations.

2.3 System Performance Metrics

2.3.1 Key Performance Indicators (KPIs)

Metric	Formula	Unit	Description
Performance Ratio (PR)	PR = (Actual Energy Output) / (Theoretical Energy Output)	%	Measures how effectively the system converts sunlight to electricity compared to its theoretical capability
Capacity Factor (CF)	CF = (Total Energy Generated) / (Rated Capacity × Hours in Period) × 100	%	Ratio of actual energy output to potential output if operated at full capacity
Specific Yield	Specific Yield = Total Energy Generated (kWh) / Installed Capacity (kWp)	kWh/kWp	Energy generated per unit of installed capacity

2.4 Performance Calculations

2.4.1 1. Performance Ratio

```
PR = E_AC / (H_i × A × η_STC)
```

Where:

- PR = Performance Ratio

- E_AC = AC energy output (kWh)

- H_i = Solar irradiation (kWh/m²)

- A = Total module area (m²)

- η_STC = Module efficiency under Standard Test Conditions (%)

2.4.2 2. Energy Output Calculation

```
E = A × r × H × PR
```

Where:

- E = Energy (kWh)

- A = Total solar panel area (m²)

- r = Solar panel efficiency (%)

- H = Annual average solar radiation on panels (kWh/m²)

- PR = Performance ratio

2.4.3 3. System Losses

```
System Losses (%) = 100 - PR(%)
```

Common losses include:

- Temperature losses (8-12%)

- DC cable losses (1-3%)

- AC cable losses (1-3%)

- Inverter losses (2-10%)

- Shading losses (0-40%)

- Soiling losses (2-25%)

- Mismatch losses (1-4%)

2.5 System Forecasting

2.5.1 1. Monthly Energy Production Forecast

```
E_month = P_rated × PSH × n × PR
```

Where:

- E_month = Monthly energy production (kWh)

- P_rated = Installed capacity (kWp)

- PSH = Peak Sun Hours per day for that month

- n = Number of days in the month

- PR = Performance ratio

2.5.2 2. Annual Energy Yield Prediction

```
AEY = P_rated × ∑(PSH_daily × PR_daily)
```

Where:

- AEY = Annual Energy Yield (kWh/year)

- P_rated = System rated power (kWp)

- PSH_daily = Daily Peak Sun Hours

- PR_daily = Daily Performance Ratio

2.5.3 3. Degradation Analysis

```
Output_Year(n) = Initial Output × (1 - Degradation Rate)^n
```

Where:

- Output_Year(n) = Energy output in year n

- Initial Output = First year energy output

- Degradation Rate = Annual degradation rate (typically 0.5-0.8%)

- n = Number of years after installation

2.6 Weather Impact Analysis

2.6.1 1. Temperature Effect on Module Performance

```
P_actual = P_STC × [1 - γ × (T_cell - T_STC)]
```

Where:

- P_actual = Actual power output

- P_STC = Power at Standard Test Conditions

- γ = Temperature coefficient (%/°C)

- T_cell = Operating cell temperature (°C)

- T_STC = Standard Test Condition temperature (25°C)

2.6.2 2. Cell Temperature Calculation

```
T_cell = T_ambient + [(NOCT - 20)/800] × G
```

Where:

- T_cell = Cell temperature (°C)

- T_ambient = Ambient temperature (°C)

- NOCT = Nominal Operating Cell Temperature (typically 45-47°C)

- G = Solar irradiance (W/m²)

2.7 Financial Assessment

2.7.1 1. Levelized Cost of Energy (LCOE)

```
LCOE = (∑(Costs_t / (1+r)^t)) / (∑(Energy_t / (1+r)^t))
```

Where:

- Costs_t = All costs in year t

- Energy_t = Energy produced in year t

- r = Discount rate

- t = Year of operation

2.7.2 2. Return on Investment (ROI)

```
ROI = (Net Profit / Total Investment) × 100
```

Where:

- Net Profit = Total Revenue - Total Costs

- Total Investment = Initial system cost

2.7.3 3. Payback Period

```
Payback Period = Initial Investment / Annual Energy Savings
```

2.8 References

1. International Electrotechnical Commission (IEC) 61724-1 - Photovoltaic system performance monitoring

2. National Renewable Energy Laboratory (NREL) - PVWatts Calculator Methodology

3. International Energy Agency (IEA) Photovoltaic Power Systems Programme

4. ASTM E2848 - Standard Test Method for Reporting Photovoltaic Non-Concentrator System Performance