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ACCURACY COMPARISON OF METEONORM AND SOLARGIS WEATHER DATABASE FOR EFFECTIVE SOLAR IRRADIANCE AND SOLAR PV ENERGY GENERATION FORECASTING

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ABSTRACT

This paper undertakes a validation and comprehensive comparative analysis between two prominent weather databases, Meteonorm and SOLARGIS, to assess their impact on energy yield estimations for solar photovoltaic (PV) power plants. The pursuit of maximizing solar resource potential in the dynamic landscape of solar PV power generation necessitates precise weather databases. This study focuses on validation of estimated Meteonorm and SolarGIS weather data provider's data generated using PVSYST simulation software for a 10MW solar PV plant situated at Dhaka, Rajnagar Block, Birbhum District, West Bengal, India with the ground measured weather data such as Global Horizontal Irradiance (GHI), Global Tilted Irradiance (GTI), Module Temperature of Weather Monitoring Station for complete 1 year at that location and also on the intricate comparison between SolarGIS and Meteonorm, recognizing their distinct roles in enhancing the accuracy of energy generation simulations. Operating at the nexus of meteorology, technology, and energy economics, solar PV systems demand meticulous consideration of solar irradiance, meteorological parameters, and geographic intricacies. The investigation employs two different energy yield forecasting that was done for both the internationally recognised weather databases, and a comparison is made with the actual PV energy generation of the solar PV power plant. The findings reveal that the SolarGIS database provides more accurate weather data for the specific location, emphasizing its potential superiority in facilitating dependable effective solar irradiance prediction with an error of -0.36% where Meteonorm shows an error of 3.01%. It also shows yearly generation error of 10.32% and 14.93% for SolarGIS and Meteonorm respectively compared to the actual ground measured energy generation of the power plant. As solar PV systems continue to evolve, this study contributes valuable insights for engineers, researchers, and stakeholders in the selection of optimal weather databases crucial for intricate and reliable simulations.

Keywords - Photovoltaic Energy, Weather Database Validation, Weather Data Comparison, PVSYST, Meteonorm, SolarGIS, Weather Station, Solar PV Plant, Birbhum, West Bengal.

INTRODUCTION

The burgeoning global demand for renewable energy has propelled solar photovoltaic (PV) systems to the forefront of sustainable power generation. Accurate estimations of energy output are crucial for determining the optimal sizing of solar plant, assessing the economic feasibility, and predicting the energy yield over the plant's lifetime, optimizing plant performance, effective management of solar power generation and ensuring the stability of the grid. However, the seasonal variations and intermittency of the solar resource availability need to be well known in order to allow for a precise forecasting of PV generation and estimating the amount of irradiation available at any particular site is based on historical series collected for long periods (typically tens of years), which will result in fairly good approximations of what can be expected during the following years [1]. Because of the usual lack of measured data at the project’s site, the solar resource needs to be modeled in most cases. Several meteorological data platforms provide global radiation data for the horizontal plane. They differ in many aspects such as input data, covered area, methodology, time interval and spatial resolution [2]. The data contained in these databases are obtained through measurements made by solarimetric stations, estimated values calculated through interpolations or values through terrestrial mathematical models and based on satellite images.

Among these, when the accuracy of the Meteonorm and NASA SSE databases is investigated, the Meteonorm database presented more accurate solarimetric data [3]. When a validation study using Meteonorm weather data for photovoltaic energy forecasting for a 1 MW DC photovoltaic solar power station in the Anuradhapura region, Sri Lanka has been conducted, it showed an error of 1.5 %, but all other months have gone for more than 5%, which cannot be accepted for accurate energy yield forecasting. Thus, much broader study can be done using the data of longer period and comparing several other weather data sources such as SolarGIS, PVGIS, NREL, Solcast etc., which will help to identify a more accurate source [4]. The accuracy of database data is related to the distribution of meteorological stations and satellite stations, the number of sites, and the accuracy of monitoring. Meteonorm relies on a hybrid approach, combining measured data from meteorological stations with satellite-based estimates and sophisticated models. This methodology, while offering global coverage, is inherently limited by the accuracy and availability of measured data in Asia. The relative error between the measured data and the radiation data in Meteonorm database is found around 8% in a 5.6 kW PV grid-connected system in Beijing and as a result, the relative error between PV power and actual generating is estimated to be around 25% [5]. Relative error of 12-25% for hourly values has been found when validated in eleven sites of Europe, Middle East and Africa [6].

In SolarGIS, to calculate all-sky irradiance in each time step, the clear-sky GHI is coupled with cloud index. The clear-sky irradiance is calculated by the simplified SOLIS model [7], which allows fast calculation of clear-sky irradiance from the set of input parameters viz., Sun position, concentrations of atmospheric constituents, namely aerosols, water vapour and ozone. The cloud index is derived by relating radiance recorded by the satellite in four spectral channels and surface albedo to the cloud optical properties [8]. The time series used for validation represent a period from January 2007 to December 2019. When, SolarGIS model solar radiation time-series data was compared to ground measurements from five high quality stations located in Japan, it showed a very good match with the uncertainty of the annual GHI value of ±4.5 to ±6.0% [9].

This work aims to investigate the accuracy of the Meteonorm and SolarGIS irradiation data in estimation of solar power generation. The Meteonorm and SolarGIS databases are compared using real irradiation data collected from Weather Monitoring station at the Dhaka 10 MW Solar Photovoltaic Plant site, Birbhum district, West Bengal. Simulations are performed using PVSyst software and the results of energy generated are compared to the values measured at site.

PLANT OVERVIEW:

The solar PV plant located at Dhaka, Birbhum district, West Bengal, India with Latitude 24.02° N and Longitude 87.30° E is studied here. The Plant consists of cumulative solar PV array capacity with 15° fixed tilt configuration of 10.1 MW as shown in Fig. 1 below.

Module Specification:

In this plant, Vikram Solar Ltd. make polycrystalline Eldora VSP.72.335.05 model Solar PV Module of 335 Wp rating has been used. Each Module has 72 poly- crystalline 156mm X156mm solar cells connected in series. Electrical specifications [10] of the module at Standard Test Condition (STC) are furnished in **Table I** below.

Inverter Specification:

In this plant, ABB make PVS980-58-2000kVA-K model grid-tied Central Inverters of rating 2000 kW have been used. Important technical specifications [11] are furnished in **Table II** below.

Table I

Pv Module Electrical Specifications

Parameters	Value
Nominal Power (P_{max})	335 W
Maximum Voltage (V_{mp})	38.1 V
Maximum Current (I_{mp})	8.86 A
Open Circuit Voltage (V_{oc})	46.6 V
Short Circuit Current (I_{sc})	9.4 A
Module Efficiency(η_m)	17.29 %
Temp. coefficient of Power (δ)	-0.38%/°C

Table II

Inverter Electrical Specifications

Parameters	Value
Nominal Real Power	2000 kW
DC MPPT Range	935-1500 V
Max Open Ckt. Voltage	1500 V
DC Input Current	2400 A
AC Output Voltage	660 V
AC Output Current	1925 A
Maximum Efficiency (η)	98.8 %

Pyranometer Specification

In this plant, Kipp & Zonen make SMP11 model current output type Pyranometer has been used to record solar irradiance at site as shown in Fig. 2. The Pyranometer has been installed to collect irradiance at 15° tilted plane w.r.t. the horizontal surface. It has been factory set such that an output of 4 mA represents 0 W/m² and the full-scale output of 20 mA represents 1600 W/m with a nonlinearity of up to maximum 0.2%. The irradiance value (E_{solar}) for the default setting can be simply calculated as shown below [12]:

E_{solar} = (mA-4) x 100 ……………………………………………………………………….(i)

Where, E_{solar} = Solar radiation [W/m²] and mA = Output of radiometer [mA].

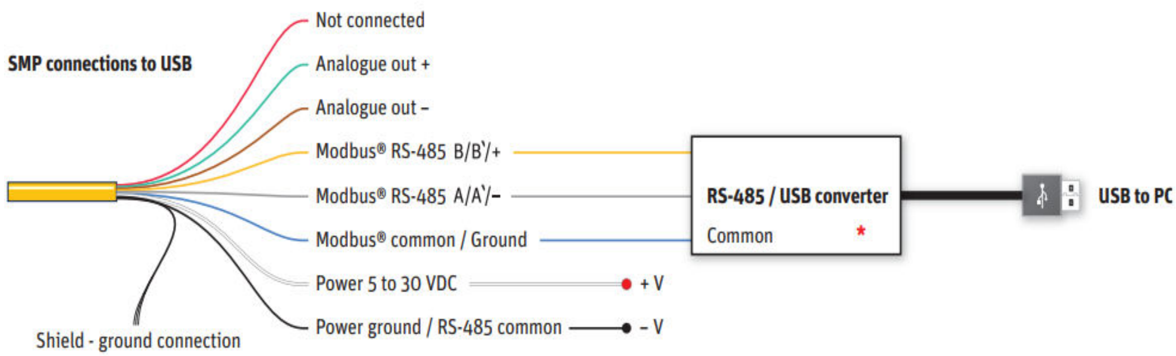


Fig. 2: Weather Monitoring System at site and the connection diagram of the Pyranometer output to the plant SCADA system

METHODOLOGY

PVsyst is a very renowned commercially available simulation software used for design, energy estimation and other analytical operations of solar PV systems. PVsyst uses numerous data such as meteorological data, PV system equipment characteristic data and various loss factors for energy generation prediction.

A 10 MW solar PV station in the Dhaka Region, Birbhum district, West Bengal, India is considered for this study. The plant consists of 30150, 335 Wp solar PV modules with 5, 2000 kW central inverters. Modules are oriented at 15° fixed tilt, 0° azimuth angle, 0.2 albedo and 6m pitch. Simulations are done for both the Meteonorm 7.2 and SolarGIS databases using PVSyst software. GHI at 15° tilted array and actual energy yield data for the whole 2022 year have been collected from the site for comparative analysis of the weather databases. Actual energy yield data has been corrected by incorporating the recorded 33kV Grid outage time for every month based on the average generation of that month and then summed up to get the yearly actual energy yield that may have been generated if no grid outage was there. The analysis has been divided into two parts as mentioned below:

a) Correlation between actual GHI at site and GHI values found from the PVSyst software for both the Meteonorm 7.2 and SolarGIS databases has been calculated to find the more accurate database.

b) Percentage between actual energy yield at site and estimated energy yield values found from the PVSyst software for both the Meteonorm 7.2 and SolarGIS databases has been calculated to find the accuracy of both the databases.

RESULTS AND DISCUSSION

The Table III & IV and Fig. 3 & 4 shows the simulated results of solar irradiance at 15° tilted Plane of Array and predicted energy generation respectively in case of Meteonorm 7.2 and SolarGIS weather database from the PVSyst software. Fig. 5 & 6 shows the graphical presentation of the above data.

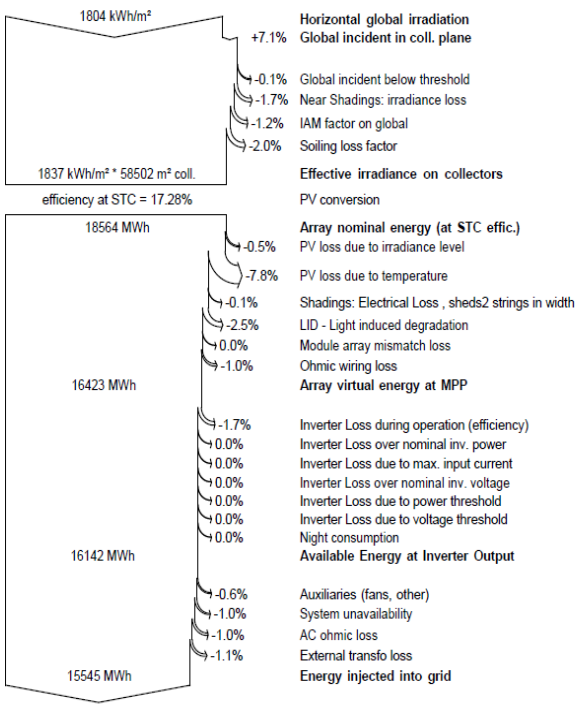
The Table V and VI shows Correlation between measured GHI at site and GHI values found from the PVSyst software for both the Meteonorm 7.2 and SolarGIS databases and Percentage between measured energy yield at site and estimated energy yield values found from the PVSyst software for both the Meteonorm 7.2 and SolarGIS databases respectively.

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray MWh	E_Grid MWh	PR
January	128.7	45.89	17.78	157.2	150.1	1377	1315	0.828
February	136.5	53.52	21.68	157.3	150.2	1364	1237	0.779
March	176.9	68.78	26.64	191.4	182.7	1613	1542	0.798
April	189.2	79.92	30.42	193.0	183.7	1598	1474	0.756
May	196.2	96.69	31.64	191.3	181.4	1580	1471	0.761
June	162.4	97.58	29.98	156.0	147.2	1305	1250	0.793
July	140.6	93.67	28.92	136.3	128.2	1148	1098	0.798
August	145.5	93.85	28.53	144.2	135.7	1219	1167	0.801
September	135.2	72.45	27.69	141.1	133.6	1192	1140	0.800
October	137.3	69.11	26.31	152.6	144.9	1300	1243	0.807
November	128.6	49.06	22.10	153.5	146.9	1335	1276	0.823
December	126.7	39.42	18.25	158.3	152.0	1393	1331	0.832
Year	1803.6	859.94	25.84	1932.2	1836.5	16423	15545	0.797

Table III: Simulated solar irradiance at 15° tilted POA for Meteonorm 7.2

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray MWh	E_Grid MWh	PR
January	123.0	63.0	17.00	145.1	137.8	1276	1220	0.832
February	138.0	61.0	20.90	157.4	150.0	1365	1159	0.729
March	185.0	77.0	26.10	200.1	190.9	1688	1613	0.798
April	192.0	86.0	31.00	195.9	186.3	1617	1547	0.782
May	185.0	101.0	33.30	180.5	170.7	1478	1416	0.777
June	149.0	95.0	31.90	143.3	134.9	1190	1140	0.788
July	136.0	91.0	29.00	131.8	123.9	1111	1065	0.800
August	141.0	90.0	28.00	140.3	132.1	1184	1133	0.800
September	136.0	80.0	27.00	141.1	133.4	1196	1144	0.803
October	144.0	73.0	24.30	159.6	151.6	1368	1308	0.811
November	125.0	64.0	20.70	144.6	137.7	1261	1205	0.825
December	113.0	61.0	17.69	133.8	127.1	1178	971	0.718
Year	1767.0	942.0	25.59	1873.4	1776.4	15913	14921	0.789

Table IV: Simulated solar irradiance at 15° tilted POA for SolarGIS



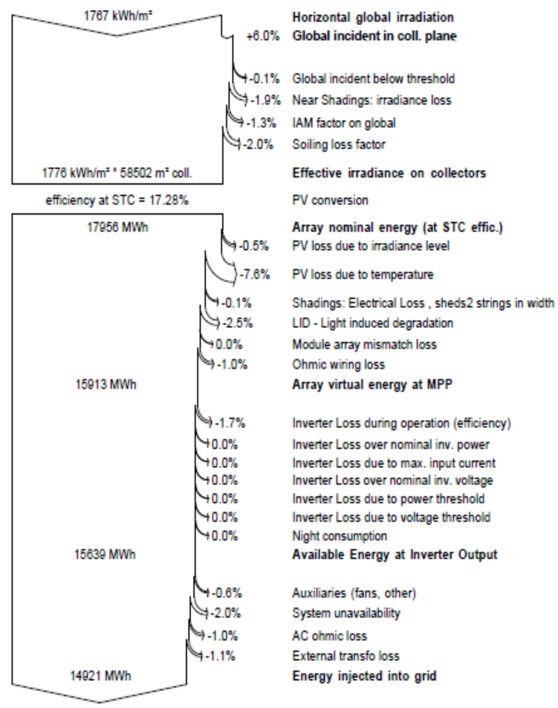


Fig. 3: Simulated energy yield for Meteonorm

Fig. 4: Simulated energy yield for SolarGIS

Table V

Correlation Between Measured Ghi At Site And Ghi Values Found From The Pvsyst Software For Both The Meteonorm 7.2 And Solargis Databases

Sl. No.	Month	Measured GHI at 15° Tilted POA (kWh/m²)	Meteonorm Predicted GHI at 15° Tilted POA (kWh/m²)	SolarGIS Predicted GHI at 15° Tilted POA (kWh/m²)	Correlation of Meteonorm GHI	Correlation of SolarGIS GHI
1	Jan-22	129.80	150.1	137.8	1.16	1.06
2	Feb-22	146.49	150.2	150	1.03	1.02
3	Mar-22	185.55	182.7	190.9	0.98	1.03
4	Apr-22	159.65	183.7	186.3	1.15	1.17
5	May-22	156.92	181.4	170.7	1.16	1.09
6	Jun-22	143.30	147.2	134.9	1.03	0.94
7	Jul-22	153.92	128.2	123.9	0.83	0.80
8	Aug-22	134.64	135.7	132.1	1.01	0.98
9	Sep-22	128.42	133.6	133.4	1.04	1.04
10	Oct-22	160.27	144.9	151.6	0.90	0.95
11	Nov-22	148.60	146.9	137.7	0.99	0.93
12	Dec-22	135.22	152	127.1	1.12	0.94
Yearly		1782.80	1836.5	1776.4	1.0332	0.9957
Deviation (%)					**3.01**	**-0.36**

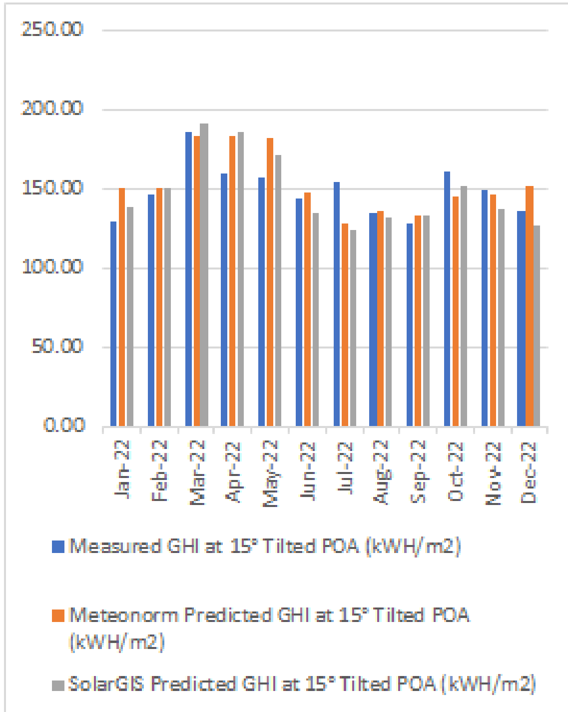


Fig. 5: Comparison of estimated and measured solar Irradiance value

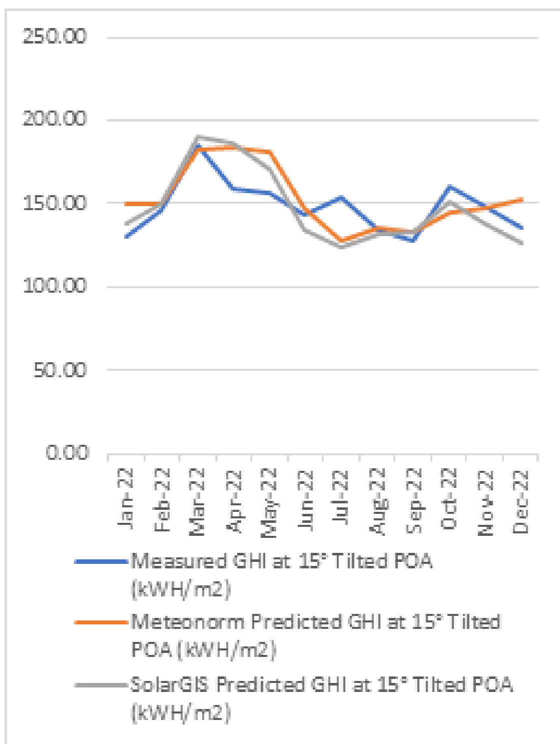


Fig. 6: Correlation between estimated and measured solar Irradiance value

Table VI

Percentage Between Actual Energy Yield At Site and Estimated Energy Yield Values Found from the Pvsyst Software for Both the Meteonorm 7.2 and Solargis Databases

Sl. No.	Month	Net Generation Export (kWh)	Generation Lost for Grid Outage (kWh)	Consumption for Operation (kWh)	Total Annual Measured Generation at Site (kWh)	Meteonorm Generation Estimation (kWh)	SolarGIS Generation Estimation (kWh)
1	Jan-22	1064098	5862.85	11680.00	13525322.36	15545000	14921000
2	Feb-22	1064680					
3	Mar-22	1306240					
4	Apr-22	1294530	14997.62				
5	May-22	1214760					
6	Jun-22	1017000					
7	Jul-22	1079757	15719.50				
8	Aug-22	980970					
9	Sep-22	987220					
10	Oct-22	1189570	3027.38				
11	Nov-22	1134999					
12	Dec-22	1011731					
Shortfall in Energy Yield (%)						**14.93**	**10.32**

CONCLUSION

From the above comparative analysis between the simulated results of GHI values & Energy Yield values found from the PVSyst software for both the Meteonorm 7.2 & SolarGIS weather databases respectively and the measured GHI values & Energy Yield values for the year 2022 at the Dhaka 10MW Solar PV Plant site, it can be identified that both the simulated results have an error in GHI & Energy Yield prediction. Meteonorm 7.2 weather database shows an error in GHI value of 3.01 % and 14.93% in Energy Yield prediction for the particular site and specified scenario. Whereas, SolarGIS weather database shows an error in GHI value of -0.36 %, which means it has predicted little less values than the values found at site and 10.32% in Energy Yield prediction. However, SolarGIS data source can be identified as the more reliable weather data provider compared to Meteonorm based on the yearly and monthly data of effective GHI value at collector plane.

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