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COMPARATIVE ANALYSIS OF LATITUDE-BASED SOLAR TILT VS.

DAILY OPTIMIZED TILT: A CASE STUDY OF BHOJPUR, MADHYA PRADESH

Krishankant Shrivastava Independent Researcher
Bhopal, Madhya Pradesh,

Abstract - This research investigates the validity of the universal "Latitude-based" rule for solar panel tilt angles in the region of Bhojpur, Madhya Pradesh. By analyzing 365 days of solar altitude data, the study quantifies the deviation between a fixed tilt and a daily optimized tilt. The results indicate that while the latitude rule is a convenient "Thumb Rule," it leads to significant efficiency gaps during seasonal extremes, suggesting that dynamic or seasonal adjustments are superior for maximum energy harvesting**.**

***IndexTerms* -** Solar Energy, Tilt Angle Optimization, Bhojpur, Solar Altitude, Latitude Rule Deviation

I. INTRODUCTION

In the solar energy industry, the most common "Thumb Rule" is that a solar panel's tilt angle should be kept equal to the local latitude to achieve the best year-round performance. However, the practical accuracy of this rule is often questioned. This research tests this assumption specifically for Bhojpur (23.10°N), evaluating whether a static installation truly serves the purpose throughout the year. As the sun's path changes daily, a fixed angle might lead to substantial energy loss. This paper provides a data-driven analysis of these deviations to suggest a more optimized approach.

II. RESEARCH METHODOLOGY

The research follows a systematic data-driven approach:

- **Location Selection:** Bhojpur, Madhya Pradesh (23.10° N).
- **Data Acquisition:** Peak solar altitude angles (α) for all 365 days of 2025-2026 were collected using Timeanddate.com and the LuneSolCal application.
- **Mathematical Modeling:** The "Daily Ideal Tilt" (β) was derived using the formula:

  $\beta = 90 - \alpha$(Eq.1)

- **Comparison:** A "Deviation/Error" calculation was performed in Microsoft Excel to find the difference between the Daily Ideal Tilt and the Local Latitude (23.10° N)

	A	B	C	D	E	F
1	Date	Day	Peak Altitude angle	Ideal Tilt Angle	Local Lattitude	Deviation(Error)
2	01-01-26	1	43.9	46.1	23.10	23.00
3	02-01-26	2	44	46	23.10	22.90
4	03-01-26	3	44.1	45.9	23.10	22.80
5	04-01-26	4	44.2	45.8	23.10	22.70
6	05-01-26	5	44.3	45.7	23.10	22.60
7	06-01-26	6	44.4	45.6	23.10	22.50
8	07-01-26	7	44.6	45.4	23.10	22.30
9	08-01-26	8	44.7	45.3	23.10	22.20
10	09-01-26	9	44.8	45.2	23.10	22.10
11	10-01-26	10	45	45	23.10	21.90
12	11-01-26	11	45.1	44.9	23.10	21.80
13	12-01-26	12	45.3	44.7	23.10	21.60
14	13-01-26	13	45.5	44.5	23.10	21.40
15	14-01-26	14	45.6	44.4	23.10	21.30
16	15-01-26	15	45.8	44.2	23.10	21.10

Table 1: Sample of Solar Altitude and Ideal Tilt Calculation (Jan1- Jan15)

III. RESULTS AND DISCUSSION

Table 1: Sample of Solar Altitude and Tilt Calculations (January) | Date | Peak Altitude (α) | Ideal Tilt (β) | Local Latitude | Deviation | | :--- | :--- | :--- | :--- | :--- |

| 01-01-26 | 43.91 | 46.1 | 23.10 | 23.00 |

| 05-01-26 | 44.35 | 45.7 | 23.10 | 22.60 |

| 10-01-26 | 45.00 | 45.0 | 23.10 | 21.90 |

| 15-01-26 | 45.85 | 44.2 | 23.10 | 21.10 |

(Note: Full dataset contains 365 days)

The analysis reveals that the "Thumb Rule" is only perfectly accurate twice a year, during the Equinoxes.

- **Winter Peak:** During January, the ideal tilt reaches as high as 46°, creating a deviation of +23° from the latitude rule.

- **Summer Peak:** During June, the sun is almost vertical, requiring a near-zero or negative tilt.

- **Visual Analysis:** The generated graph clearly shows a U-shaped trend of deviation, proving that a fixed 23.10° tilt is sub-optimal for more than 90% of the year.

Figure 1: Annual Deviation of Ideal Tilt from Local Latitude.

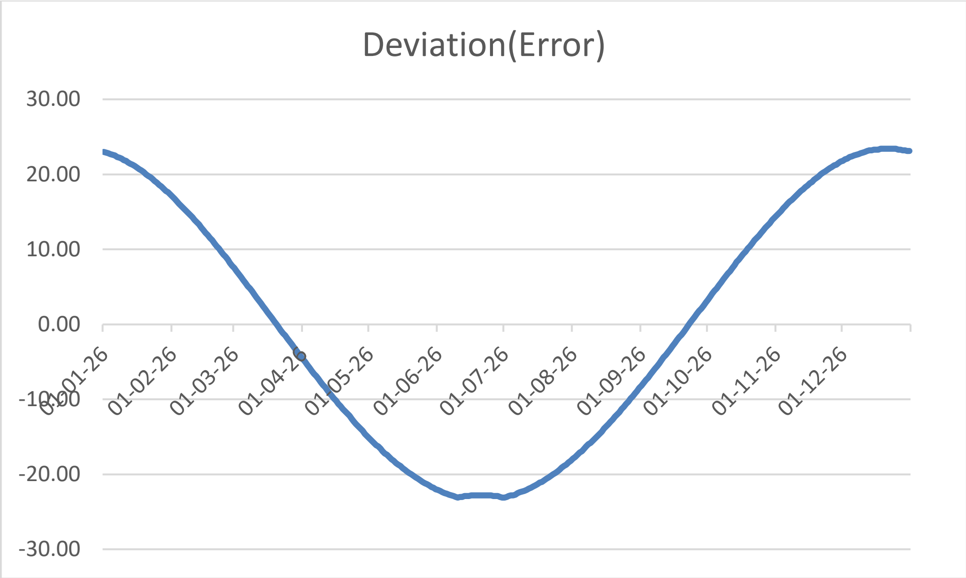

Figure 1: Annual Deviation of Ideal Solar Tilt Angle form Local Latitude (23.10°N) in Bhojpur.

"As illustrated in Figure 1, the deviation follows a seasonal U-shaped trajectory. The positive values during winter months (November to February) indicate that the ideal tilt is significantly higher than the latitude, while the negative values in summer show the sun passing directly overhead. This visual data confirms that a static 23.10° tilt leads to maximum misalignment during the winter solstice."

IV. CONCLUSION

The study concludes that while setting solar panels at an angle equal to the latitude is a simple installation rule, it is not the most efficient. For Bhojpur, a fixed 23.10° tilt causes significant misalignment for most of the year. It is recommended that users adopt **Seasonal Tilting** (adjusting 2-4 times a year) to bridge the +20 gap identified in this research.

V. REFERENCES

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