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Determining the Electricity Production from a Photovoltaic cell with various Tilt approach and Facing (East-South-West) For Geelong-Victoria, Australia

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ABSTRACT : *For reliability, quest for emission reduction, carbon emission taxes, and for favorable feed-in tariff have rendered Photovoltaic (PV) installation as attractive and smart investment. PV cells are fuelled with free and renewable energy (RE) source - Solar energy, and converts in to electricity. To obtain maximum energy gain, various researchers have recommended installing PV cell with an optimum tilt angle, and facing direction for a particular location. However, due to restricted space availability, buildings and nearby object shadows, it is always not possible to install as per the researchers recommendation. Therefore, for these reasons, in this paper by considering various tilt approach, and facing for East-South-West directions, the electricity production is determined using HOMER (Hybrid Optimization Model for Electric Renewable) NREL (National Renewable Energy Laboratory) tool.*

KEYWORDS: *Photovoltaic (PV), Tilt, Facing, Electricity production.*

I. INTRODUCTION

In this contemporary world, most of the equipments we use today consume electricity in order to work; and day-by-day with the increase in population the consumption of electricity is increasing alarmingly [*1*]. In Australia, the main resource used to generate electricity is fossil fuels, whereas only a minute proportion represents RE [*2*]. The electricity generated from Non-RE sources is considered cheaper than from RE technologies [*1*]. The majority of electricity supplied to the houses by state or local power authority through grid is by 240-Volts. With respective to this, some of the house owners find the electricity supplied through grid is expensive. This is mainly due to the fact that in Australia while accounting the cost of electricity to the end users, various charges such as Network charge, Whole sale cost, Retail and energy scheme costs, and Carbon taxes are added as part of the feed-in-tariff [*2*].

Although, there are numerous ways to generate electricity, RE is considered as clean, sustainable and reliable source. Among all RE technologies, PV is considered as the most promising [*3*]; since it has many advantages such as fuelled with free resources, available abundantly, and considered to have a great potential for various applications. PV cells convert solar energy in to electric current [*4*] [*5*]; because of this the PV installation has exponentially increased in the last few years in Australia [*6*]. Like any other system, PV also needs to be operated by considering maximum possible performance. Nevertheless, the working, energy output, and performance of the PV can be enhanced by considering the installation, design, construction, tilt angle and facing [*7*]. With the facing, researchers determined that for places on the Southern hemisphere, North facing is recommended, whereas for places on Northern hemisphere, South facing is recommended; since it assists in gaining maximum energy [*8*] [*9*]. Additionally, optimal trajectories of Sun tracking system by introducing new algorithm for determining time dependent with total solar radiation on PV surface and inclusion of the tracking system consumption in the optimization procedure increase the efficiency of energy production of PV ranging 10–50%. However, the efficiency increase depends on the location as well as on the day and time in the year [*10*]. Despite of the increase in energy production, trackers are considered to be expensive and further it needs power supply for its operation, yet there is another practicable way of orienting PV - tilting optimally on time to time basis [*7*].

Furthermore, the fact that PV cannot be faced exactly as per the recommended South and North directions for Northern hemisphere and Southern hemisphere respectively as it is always not true that maximum solar energy is available or will receive at the recommended facing. There are various other factors such as shadow, constructed architecture of the house, and less space to install. In this paper by considering these issues; the directions-directly facing East, South South East (22.5° from South), South East (45° from South), East South East (67.5° from South), facing directly West, South South West (22.5° degree from South), South West (45° from South), West South West (67.5° from South), facing directly South as shown in the Figure.1 (left), and

various tilt - vertical (0° to vertical, 90° to horizontal), optimum year around (52°), adjusted throughout the year, best winter (37°) best summer (67°), and horizontal tilt approach as shown in the Figure.1(right) are considered to determine the electricity production from PV.

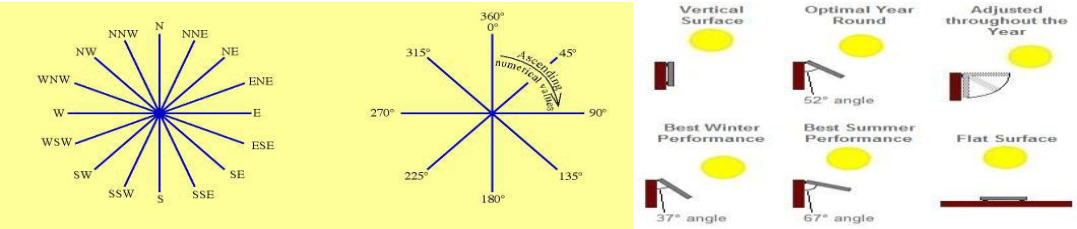

Figure.1. Directions considered from East, West, South and Intermediate facings [*11*](left), and tilt angle approach of the retrieved solar data [*12*](right)

To perform the study, solar data is retrieved from Solar electricity hand book [*12*] for Geelong area-Victoria state-Australia, subsequently, with HOMER NREL tool a PV (1 kilo-watt (kW)), converter (1kW), and primary load is enabled, the collected solar data is imported in to solar resource, and the PV electricity production is estimated.

I. SOLAR DATA FOR VARIOUS ORIENTATION

The collected solar data is plotted and is shown in the Figure.2, 3, 4, 5, and 6. The collected data for various tilt approach and facing is varying, and the same is used during the study. By comparing the overall solar radiation, directly facing South direction-tilting best summer receives the highest among various other facing directions and tilts. .

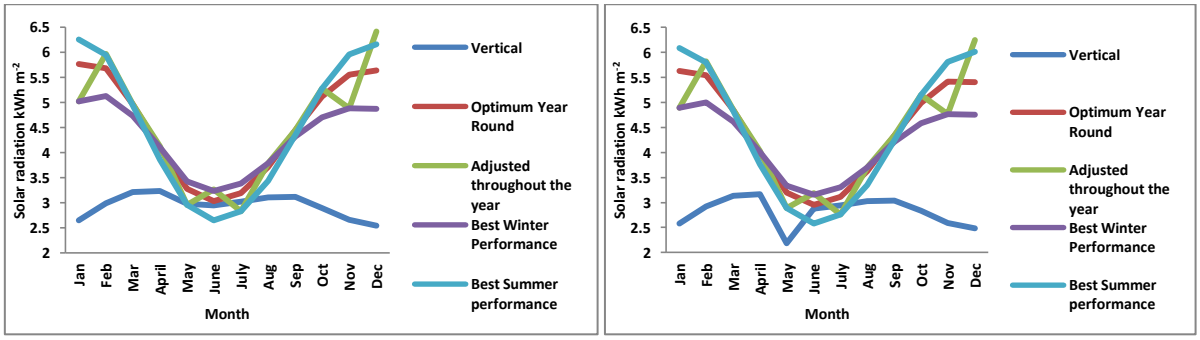

Figure.2. Solar data facing directly South (Left), and Solar data facing South South West (22.5° from South) (Right)

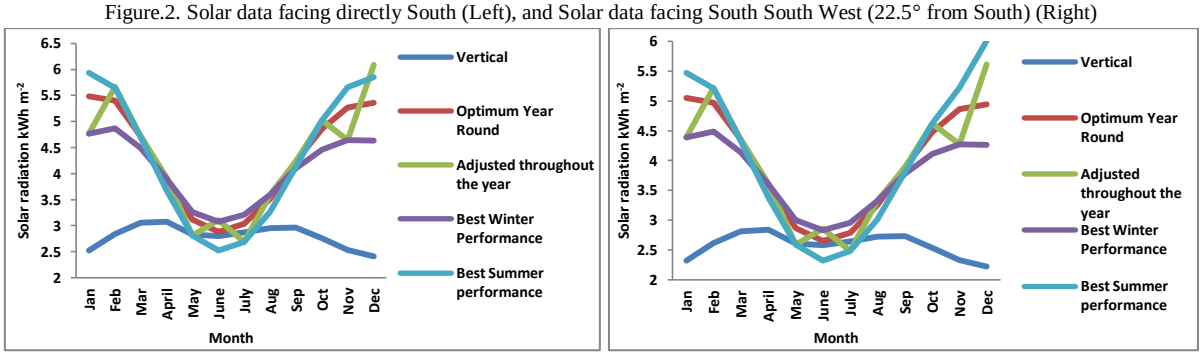

Figure.3. Solar data facing South West (45° from South) (Left) and Solar data facing West South West (67.5° from South) (Right)

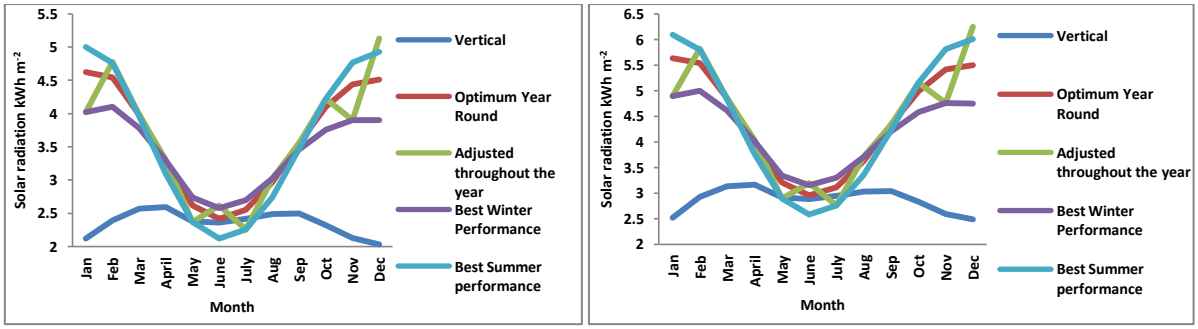

Figure.4. Solar data facing directly West (left), and Solar data facing South South East (22.5° from South) (right)

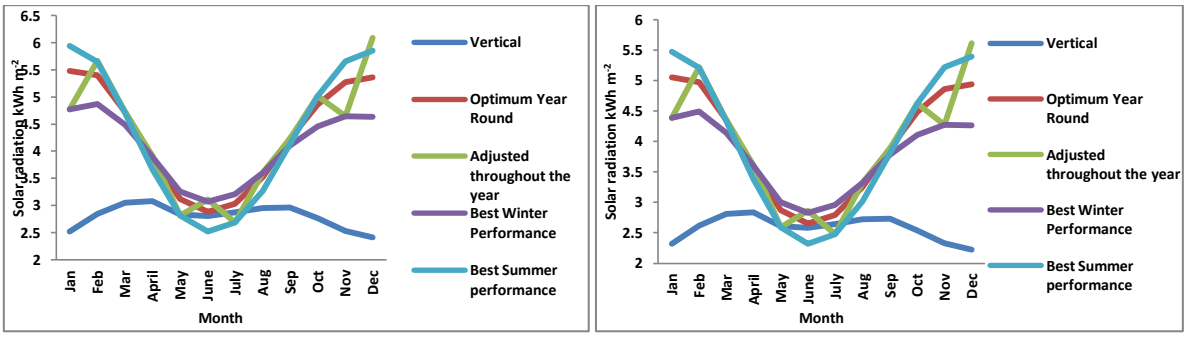

Figure.5. Solar data facing South East (45° from South) (left), and Solar data facing East South East (67.5° from South) (right)

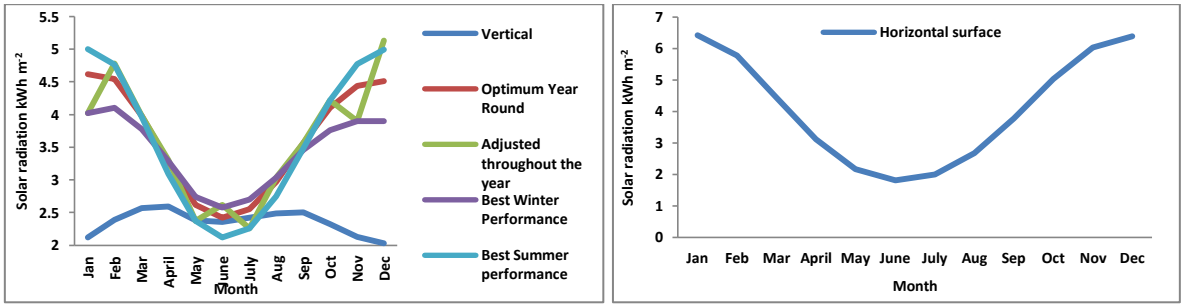

Figure.6. Solar data facing directly East (left), and Solar data facing horizontal (right)

II. RESULTS AND DISCUSSION

The electricity production for various facings, and tilt approaches are listed in Table. 1. Some interesting facts related to the electricity production are revealed by comparing average monthly electricity production of various facing directions and tilt approaches for each month to determine maximum electricity production. Beginning with the month of January, with horizontal tilt approach a maximum energy of 142.04 kW is generated, while compared to the other facing directions and tilt approaches, followed by secondly; a maximum electricity production of 132.26 kW is generated during the month of February with optimum year around tilt approach facing directly to South direction. Thirdly, by facing directly to South direction a maximum of 140.60 kW with adjustment throughout the year tilt approach is obtained during the month of March. Next, in the month of April a highest electricity production of 141.57 kW is generated facing directly in South direction and with adjusted throughout the year tilt approach. Subsequently, for the month of May, the best winter tilt approach facing South South East (22.5° from South) direction generated the maximum electricity f 150.12 kW. Furthermore, during the month of June a maximum of 165.65 kW is generated with best winter tilt approach and facing directly South direction. In the month of July, 168.55 kW as maximum electricity is produced by approaching best winter tilt approach and facing directly in south direction, for the month of August with South South East (22.5° from South) direction, and by tilting best winter, a maximum of 145.10 kW of electricity is obtained. In September, facing South South East (22.5° from South) and by tilting adjusted throughout the year a maximum electricity of 129.80 kW is generated. Turning to the month of November, a 198.91 kW of maximum electricity is produced by tilting optimum year around and facing directly East direction. Lastly, in the month of December, a maximum electricity of 139.49 kW is generated by tilting adjusted throughout the year and facing directly to South.

However by considering similar tilt approaches with respective to the facing directions-from its annual electricity production, the losses occurred are compared to South facing (as it generated highest electricity among all similar tilt approach) and the determined losses are listed below.

1) Vertical- The resulted losses are 22.13 % with directly West, 22.13% with South South East (22.5° from South), 4.93 % with facing South East (45° from South), 14.02 % with East South East (67.5° from South), 2.29 % with directly West, 22.5 % with South South West (22.5° from South), 4.93 % with South West (45° from South), and 14.02 % with West South West (67.5° from South).

2) Optimum year around- The resulted losses are 23.29 % with directly West, 23.29% with South South East (22.5° from South), 5.77 % facing South East (45° from South), 14.65 % with East South East (67.5° from

South), 2.91 % with directly West, 3.04 % with South South West (22.5° from South), 6.21% with South West (45° from South), and 14.65 % with West South West (67.5° from South).

3) Adjusted throughout year around- The resulted losses are 23.28 % with directly West, 23.28% with South South East (22.5° from South), 5.99 % with facing South East (45° from South), 14.57 % with East South East (67.5° from South), 2.84 % with directly West, 2.84 % with South South West (22.5° from South), 5.99 % with South West (45° from South), and 14.57% with West South West (67.5° from South).

4) Best summer- The resulted losses are 23.62 % with directly West, 23.62% with South South East (22.5° from South), 5.75 % with facing South East (45° from South), 14.56 % with East South East (67.5° from South), 2.68 % with directly West, 2.68 % with South South West (22.5° from South), 5.75 % with South West (45° from South), and 14% with West South West (67.5° from South).

5) Best winter- The resulted losses are 23.11 % with directly West, 23.11% with South South East (22.5° from South), 5.91 % with facing South East (45° from South), 14.60 % with East South East (67.5° from South), 3.08 % with directly West, 3.08 % with South South West (22.5° from South), 5.91 % with South West (45° from South), and 13.85 % with West South West (67.5° from South).

By comparing the overall losses, it can be noticed that the losses occurred for similar tilt approach and for different facing directions are nearly same (only minor losses). It is always not possible to change the facing and tilt at each time, so by comparing the overall comparison of the electricity production, optimum year around tilt approach facing directly South direction generated maximum electricity of 1644 kW/year - comparing with this the loss proportion in % is calculated with respective to the directions for various tilt for each facing. The obtained losses are.

1) Directly East: - with Vertical 46.28%, optimum year around-23.29%, adjusted throughout the year- 24.45%, best winter-25.66%, and best summer-25.72%.

2) South South East (22.5° from South): - with Vertical-46.28%, optimum year around-23.29%, adjusted throughout the year- 24.45%, best winter-25.66%, and best summer-25.72%.

3) South East (45° from South): - with vertical-34.42%, optimum year around-5.77%, adjusted throughout the year-7.42%, best winter-8.27%, and best summer-9.12%.

4) East South East (67.5° from South): - with vertical-40.69%, optimum year around-14.65%, adjusted throughout the year-15.87%, best winter-16.84%, and best summer-17.51%.

5) Directly West: - with vertical-32.60%, optimum year around-2.91%, adjusted throughout the year-4.31%, best winter-5.29%, and best summer-6.38%.

6) South South West (22.5° from South): - with vertical-34.85%, optimum year around-3.04%, adjusted throughout the year-4.31%, best winter-5.29%, and best summer-6.38%.

7) South West (45° from South):- with vertical-34.42%, optimum year around-6.21%, adjusted throughout the year-7.42%, best winter-8.27%, and best summer-9.12%.

8) West South West (67.5° from South: - with vertical-40.69%, optimum year around-14.65%, adjusted throughout the year-15.87%, best winter-16.30%, and best summer-16.78%.

9) Directly South: - vertical-31.02%, for optimum year around-highest, adjusted throughout the year-1.52%, best winter-2.67%, and best summer-3.40%.

10) Horizontal: - with flat-18.91%.

Table.1. Electricity production in "kW" for each month, and in a year for various tilt approach and orientation (East-South-West)

Facing	Tilt	Jan	Feb	March	April	May	June	July	Aug	Sep	Oct	Nov	Dec	Annually
Directly East	Vertical	59	51.04	66.42	77.55	93.53	107.06	104.09	111.45	66.88	55.35	56.05	58.05	883
	Optimum year around	104.03	99.32	109.62	104.41	107.06	110.91	112.15	109.71	102.49	102.69	198.91	100.43	1261
	Adjusted throughout the year	90.91	104.72	109.48	105.49	92.57	124.08	94.35	112.30	102.33	105.84	86.27	113.26	1242
	Best Winter	90.81	89.06	103.18	104.90	113.74	121.17	121.59	112.11	98.76	93.22	86.19	87.27	1222
	BestSummer	112.02	104.22	108.83	96.85	92.71	91.17	94.32	99.39	99.54	105.81	105.28	110.34	1221
South South East-	Vertical	67.67	62.59	83.23	99.51	123.78	142.20	138.08	112.08	84.46	68.45	57.52	67.96	883
	Optimum year around	125.40	122.24	136.64	135.22	141.35	147.49	150.40	140.63	129.45	127.18	119.34	120.88	1261

22.5 from South	Adjusted throughout the year	109.80	128.81	136.78	137.15	122.96	163.60	125.98	144.88	129.80	131.80	105.16	136.22	1242
	Best Winter	109.82	109.89	129.21	136.30	150.12	161.26	163.73	145.10	125.05	115.88	105.18	105.45	1222
	BestSummer	135.13	128.22	135.98	125.08	122.80	121.31	125.80	127.33	125.95	131.66	128.09	131.26	1221
South East 45 from South	Vertical	67.86	61.06	81.07	96.72	119.57	137.04	133.75	108.81	82.1	66.85	56.35	66.61	1078
	Optimum year around	122.34	119.13	132.66	130.99	136.71	142.61	144.89	135.80	125.76	123.68	116.38	118.08	1549
	Adjusted throughout the year	107.06	125.15	132.39	132.00	117.94	158.52	120.98	139.48	125.50	127.92	102.37	132.79	1522
	Best Winter	107.19	106.84	125.36	131.36	145.12	156.12	157.52	139.73	121.18	112.49	102.51	102.90	1508
	BestSummer	132.03	124.85	131.97	121.32	118.17	117.43	121.21	123.64	122.23	128.11	124.90	128.08	1494
South East 67.5	Vertical	63.05	56.12	73.71	87.20	106.54	121.63	118.08	98.27	74.42	61.06	59.90	62.42	975
	Optimum year around	113.02	109.18	121.04	117.46	121.50	126.27	128.02	122.73	113.89	113.08	107.37	109.40	1403
	Adjusted throughout the year	99.06	114.98	121.07	118.80	105.30	141.20	107.71	126.10	113.92	117.00	94.46	123.24	1383
	Best Winter	99.03	98.144	114.50	118.32	129.50	138.98	139.88	87.92	110.05	102.90	94.43	95.12	1367
	Best Summer	122.08	114.68	120.36	108.90	105.20	104.23	107.62	126.06	111.05	116.93	115.23	118.66	1356
Directly West	Vertical	59.00	51.04	66.42	77.64	93.53	107.06	104.09	87.92	66.88	55.35	56.05	58.05	1108
	Optimum year around	104.03	99.32	109.62	104.41	107.06	110.91	112.15	109.71	102.49	102.69	98.18	100.43	1596
	Adjusted throughout the year	9091	104.72	109.48	105.49	92.75	124.08	94.35	112.30	103.33	105.84	86.27	113.26	1573
	Best Winter	90.81	89.06	103.18	104.90	113.74	121.17	121.59	99.58	98.56	93.22	86.19	87.27	1557
	BestSummer	112.17	104.37	109.00	97.06	92.91	91.37	94.51	112.11	99.72	105.97	105.44	109.23	1539
South South West-22.5 from South	Vertical	69.09	62.73	83.44	99.83	83.36	142.60	138.48	112.43	84.69	68.60	57.64	68.07	1071
	Optimum year around	125.376	122.20	136.51	135.16	141.28	147.42	150.33	140.57	129.40	127.13	119.30	118.78	1594
	Adjusted throughout the year	109.80	128.81	136.78	137.15	122.96	163.60	125.98	144.88	129.60	131.80	105.16	136.22	1573
	Best Winter	109.82	109.89	129.21	136.30	15.12	161.26	163.73	144.91	125.09	115.88	105.18	105.45	1557
	BestSummer	135.13	128.22	135.98	125.08	122.80	121.31	125.80	127.33	125.95	131.66	128.09	131.26	1539
South West-45 from South)	Vertical	67.86	61.01	81.07	96.72	119.57	137.04	133.75	108.87	82.1	66.85	56.35	66.61	1078
	Optimum year around	122.34	119.13	132.11	130.99	136.71	142.61	144.89	135.80	125.76	123.68	116.38	118.08	1541.9
	Adjusted throughout the year	107.06	125.15	132.39	132.00	117.94	158.52	120.98	139.48	125.50	127.92	102.37	132.79	1522
	Best Winter	107.19	106.84	125.36	131.36	145.12	156.12	157.52	139.13	121.12	112.41	102.51	102.90	1508
	BestSummer	132.03	124.84	131.97	121.32	118.17	117.43	121.21	123.64	122.23	128.11	124.90	128.08	1494
South West-67.5 from South	Vertical	63.50	56.12	73.71	87.2	106.58	121.63	118.08	98.27	74.42	61.06	51.90	62.42	975
	Optimum year around	113.20	109.18	121.04	113.46	121.78	126.21	128.02	122.73	113.89	113.08	107.97	109.40	1403
	Adjusted throughout the year	99.06	114.98	121.07	118.80	105.30	141.20	107.71	126.10	113.92	117.00	94.46	123.24	1383
	Best Winter	99.06	114.98	121.07	118.80	105.30	141.20	107.71	126.10	113.92	117.00	94.46	123.24	1376
	BestSummer	122.01	114.60	120.27	108.79	105.10	104.12	107.50	111.31	110.96	116.84	115.16	131.25	1368
Directly South	Vertical	60.26	64.11	85.73	102.86	128.04	147.35	143.85	87.92	66.88	55.35	56.05	59.31	1134
	Optimum year around	128.30	125.41	140.41	139.55	146.13	153.11	155.93	109.71	102.49	102.69	98.18	122..68	1644
	Adjusted throughout the year	112.54	132.26	140.60	141.57	127.12	168.25	130.75	112.30	102.33	105.84	86.27	139.43	1619
	Best Winter	112.40	112.69	132.72	140.42	155.36	165.65	168.55	112.15	98.76	93.22	86.19	107.78	1600
	BestSummer	138.61	131.86	140.04	129.71	127.20	126.33	130.85	99.39	99.54	105.81	105.28	131.45	1588
Horizontal	Flat	142.04	127.91	123.85	98.21	82.35	72.46	79.67	96.35	110.08	128.44	133	139.06	1333

II. CONCLUSION

HOMER NREL software tool predicted the electricity production using 1 kW PV cell for both tilt approach and facing (East-West-South) direction. The study determined that the electricity production is unpredictable and there is not a particular facing, and tilt approach which generates maximum electricity during all the time. However, by comparing the annual electricity production from the study it was determined that with optimum year around tilt approach facing South direction generated maximum electricity, followed by adjusted throughout the year tilt approach facing directly South direction, best winter tilt approach facing directly South direction, South South West (22.5° from South) direction with optimum year around tilt approach, facing directly South direction with best summer tilt approach, South South East(22.5° degree from south) direction with adjusted throughout year tilt approach, South South West (22.5° from South) direction with adjusted

throughout the year tilt approach, South South West (22.5° from South) direction with best winter performance tilt approach, South South East(22.5° from South) direction with best winter tilt approach, South East (45° from South) direction with optimum year around tilt approach, South South West (22.5° from South) direction with Best summer performance tilt approach, South South East(22.5° from South) direction with best summer tilt approach, South West (45° from South) direction with adjusted throughout the year tilt approach, South East (45° from South) direction with better winter tilt approach, South East (45° from south) direction with better summer tilt approach, South West (45° from South) direction with best summer performance tilt approach, South East (45° from South) direction with best summer tilt approach, East South East (67.5° from south) direction with optimum year around tilt approach, South West (67.5° from South) direction with optimum year around tilt approach, West South West (67.5° from South) direction with adjusted throughout the year tilt approach, West South West (67.5° from South) direction with best winter tilt approach, East South East (67.5° from South) direction with adjusted throughout year tilt approach, East South East (67.5° from south) direction with best winter tilt approach, East South East (67.5° from south) direction with best summer tilt approach, Horizontal (Flat), Facing directly west direction with optimum year around tilt approach, facing directly East direction with optimum year around tilt approach, facing directly East direction with adjusted throughout year tilt approach, Facing directly West direction with adjusted throughout the year tilt approach, facing directly West direction with best winter tilt approach, facing directly East direction with best winter tilt approach, facing directly East direction with best summer tilt approach, facing directly West direction with best Summer tilt approach, facing directly South direction with tilt approach vertical tilt approach, South South East(22.5° from south) direction with Vertical tilt approach, South West (45° from South) direction with vertical tilt approach, South East (45° from South) direction with vertical tilt approach, South South West (22.5° from South) direction with Vertical tilt approach, West South West (67.5° from South) direction with Vertical tilt approach, East South East (67.5° from South) direction with vertical tilt approach, facing directly East direction with vertical tilt approach, and facing directly west direction with vertical tilt approach.

III. FUTURE WORK

This study is an analytical analysis (software-based simulation), is based on the collected solar data of East-South-West directions, whereas the study on East North East -North-West North West directions are also essential and an experimental work is necessary to validate the obtained results.

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