International Journal of Current Engineering and Technology
E-ISSN 2277 – 4106, P-ISSN 2347 – 5161
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Research Article

Indian Climate Based Weighted Conversion Efficiency of Solar Photovoltaic Inverter for North and South Zone

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Received 10 May 2017, Accepted 25 July 2017, Available online 27 July 2017, **Vol.7, No.4 (Aug 2017)**

Abstract

PV inverter is main component of any solar photovoltaic power plant. Efficiency of photovoltaic inverter depends upon mainly weather profile, which is not same always. To find out conversion efficiency of inverter, globally two weighted methods were introduced as EURO and CEC efficiency which are based on irradiation profile of Europe and California where as Indian irradiation profile is different from Europe and California. This paper is introducing new weighted factors for efficiency calculation as per irradiation profile in Indian. Where two zones are selected as North Zone (Rajasthan, Gujrat and Madhya Pradesh) and South Zone (Telangana, Andhra Pradesh, Karnataka and Chennai) named India-North-Efficiency & India-South-Efficiency as both regions have different Irradiation profile. These methods consider the irradiation distribution over the whole annual sunny time, impact of temperature and prioritize the range with various weight factors.

Keywords: *Conversion efficiency, Indian weighted conversion efficiency, PV inverter efficiency, Solar PV inverter*

1. Introduction

In present era, due to limitations of fossil fuels and incremental demand of electricity India is quickly moving towards wind and solar energy sources as they are sustainable, free and zero carbon emissive sources which are also helping in minimizing global warming effect. As per MNRE Physical Progress Report till Feb, 2017 India has installed almost 9566.6 MW of solar power plants [MNRE, 2015]. Also, government is enforcing private sectors to invest in solar power plants with very attractive government national as well as state policies. Indian solar market expanding rapidly so, many PV inverter manufacturers are approaching to Indian market for sell purpose. Hence now a day, Indian project developers have so many choice in PV inverters but problem is how to select a max profitable inverter which have high efficiency and results in maximum generation/revenue. All solar PV inverters' efficiency depends upon their input, but using equation (1) is not useful in context of solar PV inverter.

$$Efficiency = \frac{\int P(ac)\,dt}{\int P(dc)\,dt} \quad (1)$$

As, PV inverter is having two major parts as MPPT (Maximum Power Point Tracker) section and DC to AC conversion section, both have their own efficiency. Due to development in technology and economical barrier, almost all manufacturers are using same MPPT technique hence resulting in almost same efficiency in MPPT section.

The other part is efficiency of conversion section, which is always not same for a same device as it depends upon input. And all manufacturer provides maximum efficiency which is calculated for a specific input where there it is maximum. In case of solar PV inverters input is dc power, generated by PV modules. Whereas performance of PV modules is directly affected with weather conditions. So, it can be stated that PV inverter performance/conversion efficiency is depending upon weather condition. In way to find solution to the problem, there were two methods proposed in past as Euro efficiency in 1991 and CEC efficiency, but these two conversion efficiencies are based upon Europe and Californian climate conditions [Auf den Spuren von, June 2004] [CEC, 2006] also Euro efficiency method utilized hourly data of irradiation to calculate weighing factors [B. Berger et. Al, 2009] whereas CEC method doesn't considered effect of ambient temperature to this.

Weighted factors used for Euro and CEC are represented in Table-1. Indian climate conditions are very different from Europe and California, even though India itself is not having same climate condition at every place.

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Table 1 Weightage factors as per Euro and CEC

% Loading	5%	10%	20%	30%	50%	75%	100%
Euro	0.03	0.06	0.13	0.10	0.48		0.20
CEC		0.04	0.05	0.12	0.21	0.53	0.05

In this paper, as per Indian climate two new weighted coefficients are introduced for north and south zone where north zone includes Rajasthan, Gujrat and Madhya Pradesh and South zone includes Telangana, Andhra Pradesh, Karnataka and Tamil Nadu. Reason behind selecting these area is that these are having high potentials for solar power generation w.r.t. other states [Solar GIS, 2012]. This will help in calculating more appropriate conversion efficiency for the inverters and result will lead into selection of suitable inverter which will results in higher generation as well as increased revenue.

2. Study of Indian Climate Condition

Area of India is 3.287 million km2 which is very large. A large and typical geographical condition make its climate conditions very different from European and Californian climate conditions [ILKER, 2013]. Below Fig-1 shows annual temperature profile for north and south zone. Also, Fig-2 indicates histogram of one-year irradiation profile for north and south zone where data source is Meteonorm version 7 software. Fig-2 shows that for India North zone almost 45% of solar power is harvested above 800 w/m2 which is very different from Europe or California. Also, difference between north and south profile is observed.

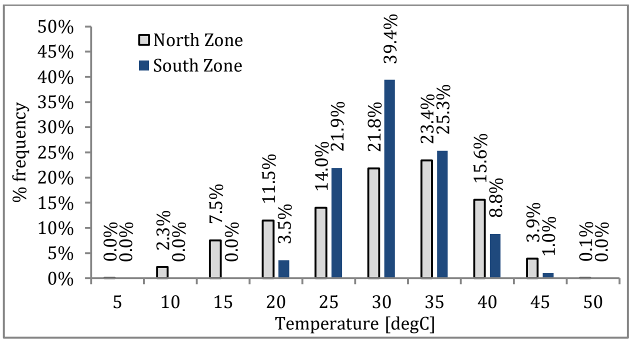

Fig.1 Histogram of ambient temperature profile for north and south zone over a year (Meteonorm-7)

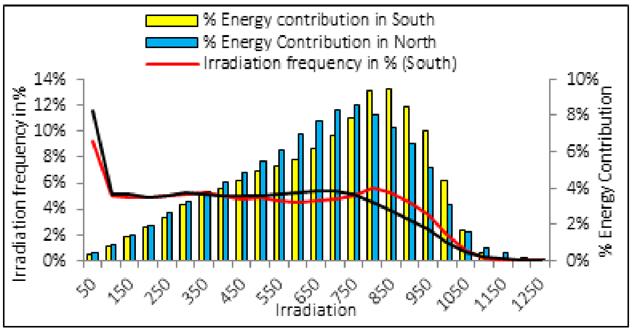

Fig.2 Histogram of one-year irradiation profile for north and south zone (Meteonorm-7)

3. Calculating New Weightage for India

For more realistic and appropriate results, minute-wise data of irradiation and ambient temperature is selected from Meteonoem version-7 software, which utilized 10 years' historical data (1990 to 2000) for predicting weather profile for specific area. Also for energy analysis, instead of considering irradiation data itself as input power to inverter, this paper considers calculated PV panel output which will be more realistic as it will involve the effect of temperature too. The selected polycrystalline PV module is of 310 Wp capacity having details as Table-2.

Table 2 Details of Typical Polycrystalline PV Module

Typical Electrical data of PV Module (STC: Irradiance 1000 W/m2, Cell Temperature =25 C, Air Mass AM1.5 as per EN 60904-3)		
Parameter	*Value*	*Unit*
Peak Power Watts- P_{MAX}	310	Wp
Power Output Tolerance	±3%	%
Maximum Power Voltage – V_{MPP}	37	Volt
Maximum Power Current – I_{MPP}	8.38	A
Open Circuit Voltage - V_{OC}	45.5	Volt
Short Circuit Current – I_{SC}	8.85	A
Module Efficiency	16%	%
Nominal Operating Cell Temperature [NOCT]	44°C (±2°C)	°C
Temperature Coefficient of P_{MAX}	-0.41	%/°C
Temperature Coefficient of V_{OC}	-0.32	%/°C
Temperature Coefficient of I_{SC}	0.05	%/°C

Steps for calculation

1. Cell temperature is calculated as per equation (2) as it is a factor affecting output of PV modules:

$$(Tcell) = Tamb. + (NOCT - 20) * \frac{GHI}{800} \quad (2)$$

2. Calculated cell temperature in step-1 and GHI values are being used for calculation of I_{sc} (short circuit current) and V_{oc} (open circuit voltage). As per equation (3) & (4).

$$Isc = Istc * \frac{GHI}{Gstc} * (1 + a * (Tcell - Tstc)) \quad (3)$$

$$Voc = Vstc * (1 + b * (Tcell - Tstc)) \quad (4)$$

3. Now simply power $P = V_{oc} * I_{sc} * FF$ (where FF = fill-factor of modules) is calculated. This is maximum DC power input for that irradiation and temperature and same is converted to energy.

4. This Energy is further treated with %loading which is nothing else but available power/rated power and reached to this table-3 & 4

Table 3 Calculation of Weightage Factor

X% Loading	5%	10%	15%	20%	25%	30%
Energy for X%	143.3	326.02	524.98	629.07	927.72	1109.8
Total Energy	33544	33544	33544	33544	33544	33544
Wtg.	0.0043	0.0097	0.0157	0.0188	0.0277	0.0331

Table 4 Calculation of Weightage Factor

X% Loading	45%	50%	75%	85%	90%	95%
Energy for X%	1771.2	2229	4046	2838.8	1336.7	103.68
Total Energy	33544	33544	33544	33544	33544	33545
Wtg.	0.0528	0.0664	0.1206	0.0846	0.0398	0.0031

Table 5 Weighted Coefficients for Calculation of Conversion Efficiency

Loading %	5%	10%	20%	30%	50%	75%	100%
Euro	.03	0.06	0.13	0.10	0.48		0.2
CEC		0.04	0.05	0.12	0.21	0.53	0.5
India North Euro	0	0.01	0.04	0.07	0.22		0.66
India North CEC		0.01	0.04	0.07	0.22	0.48	0.18
India South Euro	0	0.01	0.03	0.06	0.20		0.69
India South CEC		0.01	0.03	0.06	0.20	0.44	0.25

Here wtg. = weighting factor

Initially weightages are calculated for the same % loading described for Euro and CEC, with suffixed name as Indian_North_Euro, Indian_South_Euro, Indian_North_CEC & Indian_South_CEC.

Now the new weightage with respect to Euro and CEC are as table-5:

Formula for utilizing above mentioned weightage:

For Indian_North_Euro/Indian_South_Euro

$$\alpha1*\eta5\% + \alpha2*\eta10\% + \alpha3*\eta20\% + \alpha4*\eta30\% + \alpha5*\eta50\% + \alpha6*\eta100\% \quad (5)$$

For Indian_North_CEC/Indian_South_CEC

$$\alpha1*\eta10\% + \alpha2*\eta20\% + \alpha3*\eta30\% + \alpha4*\eta50\% + \alpha5*\eta75\% + \alpha6*\eta100\% \quad (6)$$

Here: α1, α2, α3, α4, α5, α6 are weighted factors which are to be used using Table-5 and ηx% is efficiency at x% of loading.

4. Result

Used equation (5) & (6) with table-5 to calculate efficiency of a SMA make Central inverter for both North and south zone.

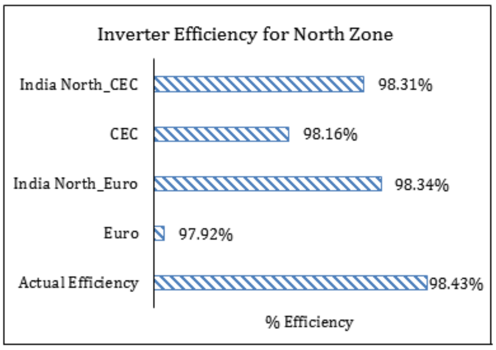

Fig.3 Conversion efficiency comparison by various methods for north zone India

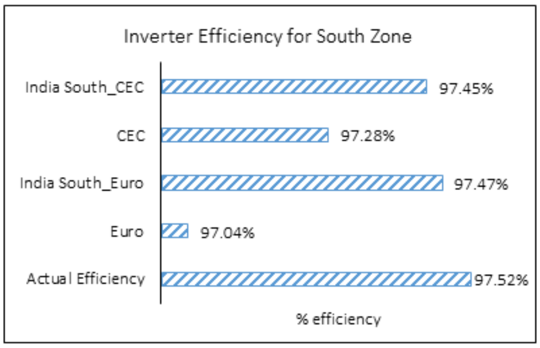

Fig.4 Conversion efficiency comparison by various methods for south zone India

As Fig-3 & Fig-4 shows that Indian North_Euro and Indian South_Euro are providing more realistic results whereas Euro efficiency values are far away from actual observed efficiency. Hence final north zone and south zone efficiency weighing factor are:

Table 6 Weighted Coefficients for Calculation of Conversion Efficiency of PV Inverter for India

%Loading	10%	20%	30%	50%	100%
India North_Effi	0.01	0.04	0.07	0.22	0.66
India South_Effi	0.01	0.03	0.06	0.20	0.69

Conclusion

Newly proposed weighing factors for calculation of PV inverter's conversion efficiency for respective zones will help Indian project/design teams for selection of a profitable inverter based on higher efficiency. Also, it will help in more accurate prediction of yearly output of inverter. The model is developed depending upon the historical data, however it is prone to radical changes in the weather conditions owing to global warming.

The same can be done for other countries/Solar zones like: Australia, Thailand, Nepal, South Africa and Gulf Country in future.

Acknowledgement

The authors sincerely acknowledge Analytics Department, Mahindra Susten Pvt. Ltd. Mumbai, India for their support during this research work.

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