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Preface

ICPRE 2017

It is our great honor and pleasure to introduce to you the Proceedings of the 2017 2nd International Conference on Power and Renewable Energy (ICPRE 2017) that will be held in the University of Electronic Science and Technology of China, Chengdu, China during September 20-23, 2017. Interest in Power and Renewable Energy with novel achievements has remarkably increased in recent years. The objective of ICPRE 2017 is to bring together a large group of researchers, scientists, academics, and engineers in the area of power and renewable energy from all over the world, who share much more than technical interests, among other things, like culture and history, etc.

We are pleased to have received over 338 submissions from 26 countries, including China, United States, Canada, United Kingdom, Germany, France, Norway, Serbia, Romania, Australia, Japan, Morocco, Egypt, Saudi Arabia, Nigeria, Indonesia, Bangladesh, Algeria, Iran, India, Thailand, Turkey, VietNam, Sultanate of Oman, Rwanda, and Pakistan. Those submissions provide a wide spectrum of researches in various areas such as renewable energy, micro-grid, smart grid, power management and control, electrical technology, power electronics, power transmission, automation, photovoltaic systems and engineering, power system, electric vehicle application, and system simulation. All the submissions are peer-reviewed. Due to constrain of number of papers in the proceeding and suitability of the topics of the submissions, 211 submissions are accepted as full papers to be presented in ICPRE 2017. It has really been a difficult task to select the most representative papers.

We truly believe that ICPRE will provide the best platform for all the participants to have fruitful discussions and to share ideas of researches. With high standard and high quality submissions and presetations in ICPRE, ICPRE will one day become a leading conference in this specific academic area.

Finally, we do wish all of you to enjoy ICPRE 2017, and to take this opportunity to have future international collaborations.

Prof. Lu Li
Prof. Ching-Fuh Lin

Conference Chairs of ICPRE 2017

Location Specific Weighted Conversion Efficiency Coefficients for Solar Photovoltaic Inverter Using R

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Abstract—**Globally solar photovoltaic power generation business is increasing rapidly as it is a clean and green method for generating power. Solar photovoltaic inverter is main component of any solar photovoltaic power plant. Generated power and revenue is directly dependents upon the conversion ratio of DC to AC. whereas conversion ratio/efficiency further depends upon DC power level/Loading or solar irradiation and ambient temperature, which is different for all location. This paper deals with identifying new weighted coefficients for specific location for conversion efficiency calculation using R-language based model. Which will help in selecting suitable solar photovoltaic inverter leading to high annual generation and revenue.**

Keywords-conversion efficiency; indian weighted conversion efficiency; PV inverter efficiency; solar PV inverter

I. Introduction

In present era world is quickly moving towards digitalization. This has become a new parameter for identifying country's development and growth. Also population is still increasing, resulting per day per person electrical energy utilization rate is increasing. Demand of electrical energy is increasing day by day. As it is a universal law that "Energy cannot be created nor be destroyed, it can only be converted from one form to another." So for fulfilling demand of electrical energy other energy source is required which has a potential of it. For conversion of electrical energy world is using bio-fossil materials as coal, natural gasses, wood etc. But they are not available in ample amount. Most of part has been already utilized for conversion of electrical energy. Also while burning bio-fossils as they are organic materials they produce CO_2 as by products and this carbon emitting results in incremental effects of global warming which is a major environmental issue now days. Water's kinetic energy is also utilizing in conversion of electrical energy. But building dam everywhere is not an easy task, this creates a boundary for limited use of hydro energy as per availability.

For overcoming problems of carbon emission, global warming and plenty of energy sources; world is quickly moving towards green energy. Green energy means environmental energy sources which are unlimited in terms of availability and also less/zero carbon emitting sources. Most famous green energy sources are wind and solar. Wind energy is being utilized using wind turbines. Where wind energy is converted into electrical energy. As wind turbine is a rotating machine so it will be requiring a dedicated scheduled maintenance. This increases the running cost of wind turbine power plants. Solar energy is utilized in two forms as solar PV [photovoltaic] and solar thermal. Solar thermal is same as a conventional thermal power plant; the only difference is it that in this boiler is operated using heat generated by solar energy instead of coal/gas/diesel etc. As this system is also having turbines and generators which will again require a scheduled maintenance hence running cost will be high. On the other hand, solar PV technology is completely different, in this technology silicon based semiconductor photo diodes are used known as photovoltaic panel/modules (Now days many more thin-film modules are available as CdTi). They convert solar irradiation into DC [Direct Current] electrical energy. But whole world is utilising electrical energy in terms of AC [Alternating Current]. In PV power plants inverters are used for converting DC energy into AC energy. As it has no any moving parts so it seems to be a robust/ less maintenance required power plant. Solar PV Plant has a low running cost and also it is very easy to build. Hence whole world is quickly moving towards installing solar photovoltaic power plants across the world.

A basic solar photovoltaic plant is having photovoltaic panels connected in series and parallel as per requirement and finally connected to inverter for AC electrical energy output.

The solar PV power plant is fully driven by inverter and this inverter is quite different from day-to-day inverters, That's why they are called PV inverters. Now PV inverter is considered as heart and brain of any PV power plant. It is considered as brain because it controls the input from solar PV modules using its MPPT [Maximum Power Point Tracker] modular. And Termed heart as it plays an important role of grid synchronism which gives a feedback of at which frequency the whole DC will be converted into AC. So performance of PV inverter has a very high impact on performance of any solar PV power plant.

In solar PV power plant as main source of energy is sun and it is changing its location at every minute, so irradiation energy will be different at any point of time. Also ambient temperature will be very for all the time. Resulting output from PV panels will be different at all time which is nothing else but input DC power for PV inverter.

In global market whenever a PV inverter is manufactured, It's efficiency is being calculated. Efficiency of any product tells about performance of that particular. As every electronics device performance is get affected with temperature and loading/burden, similarly in case of PV inverter also efficiency varies from point to point when there is a different loading and temperature. This point to point efficiency is being calculated as per:

$$Efficiency = \frac{\int Output\ Power\ dt}{\int Input\ Power\ dt} \quad (1)$$

As per equation (1) when efficiency is calculated for particular loading/burden for photovoltaic inverter, the efficiency curve will be somewhat like:

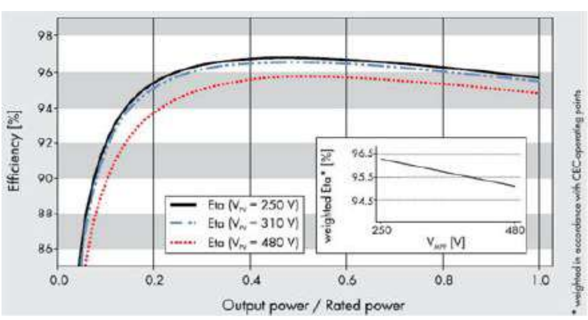

Figure 1. Efficiency plot of commercial PV inverter [1].

All inverter manufacturers share the maximum efficiency which will be only at a single X percentage loading. But inverter never runs on a fix loading in photovoltaic power plant. So the definition of maximum efficiency is not helping out in selection of an inverter.

For sorting out this problem first step was taken from Europe in 1991 that a weighted conversion efficiency should be calculated and hence the first weighted conversion efficiency calculation was done on bases of irradiation profile and north-western Germany climate data was used for the same. [2] [3]. The formula given in the magazine article becomes a well-known formula known as "European Efficiency" [4] This formula was as:

$$\eta_{EURO} = \sum_{i=1}^{6} \alpha i * \eta i \quad (2)$$

where the 6 stages were % loading as 5%, 10%, 20%, 30%, 50% & 100%.

And values of respective "α" are as per below table: (see Table I).

TABLE I. EURO EFFICIENCY WEIGHTAGE

%Load	5%	10%	20%	30%	50%	100%
α	0.03	0.06	0.13	0.10	0.48	0.20

This formula was adopted by all the inverter manufacturer as many of them are Europe based companies. But this method has some limitations as it uses hourly irradiation data and also more priority to lower irradiation zones.

To overcome this problem California Energy Commission introduced new CEC weighted efficiency method with utilizing Sacramento climate data. This also use the same methodology used in Euro Efficiency as per formula [2], but defined new weighted factors as per:

TABLE II. CEC EFFICIENCY WEIGHTAGE

%Load	10%	20%	30%	50%	75%	100%
α	0.04	0.05	0.12	0.21	0.53	0.05

But CEC efficiency also failed to meet expected results as they don't consider temperature effect.

Also they used location specific irradiation data, and due to tilt angle of earth and rotation around sun, every location has a different irradiation profile as well as different ambient temperature characteristics.

So here the problem is when a manufacturer provides max. efficiency, Euro efficiency and CEC efficiency and solar plant. So the definition of maximum efficiency is not helping out in selection of a PV inverter.

II. CHALLANGE

The challenge is when a manufacturer provides maximum efficiency, Euro efficiency and CEC efficiency and solar photovoltaic site location is not Germany and Sacramento then on what basis selection inverter should be done?

To resolve this, issue many people are working in same filed and come up with new weighing efficiencies models as Mr. Engin Ozdemir in 2013 find out weighing factors for Izmir, Turkey [5]

Also Mr Hariharan Krishnamurthy in 2014 finds out weighing factor for Chennai, India location particularly. [6]

In this paper creating a R-Program based on R Language as it is open licence data analytical tool. Which will be capable of generating weighing factor as per site location in world while giving input data of irradiation in w/m^2 and ambient temperature in °C for a year with minute resolution. It will consider the effect of temperature as well as higher accurate because of using minute wise data.

III. METHODOLOGY USED

For creating R-program for finding weighing factors for conversion efficiency calculations some basic formulas used.

Step-1: Calculate cell temperature using climate data:

$$(Tcell) = Tamb. + (NOCT - 20) * \frac{GHI}{800} \tag{3}$$

Step-2: Calculation of Current I_{SC} as:

$$Isc = Istc * \frac{GHI}{Gstc} * (1 + \alpha * (Tcell - Tstc)) \tag{4}$$

Step-3: Calculation of Voltage V_{OC} as:

$$Voc = Vstc * (1 + \beta * (Tcell - Tstc)) \tag{5}$$

where β is temp coefficient for V_{OC} in %/ºC

Step-4: After Calculating instantaneous V_{OC} and I_{SC} for particular climate condition Calculation of Power is being done.

Step-5: After calculation of power segment wise energy is calculated which is:

$$\sum (\text{Power})/60 \tag{6}$$

Step-6: Now % loading is being calculated which is ratio of available yield with total/rated yield.

Step-7: Now weightage will be ratio of available energy with total energy per loading segment.

Step-8: Using these calculated weightages in below formula will give more accurate efficiency:

$$\eta_{New} = \alpha_1 * \eta_{10\%} + \alpha_2 * \eta_{20\%} + \alpha_3 * \eta_{30\%} + \alpha_4 * \eta_{50\%} + \alpha_5 * \eta_{75\%} + \alpha_6 * \eta_{100\%} \tag{7}$$

Here $\eta_{x\%}$ stands for efficiency of inverter in particular x% of loading range.

This efficiency is calculated as:

$$\text{Efficiency for } x\% \text{ loading} = \frac{\int Pac\, dt}{\int Pdc\, dt} \tag{8}$$

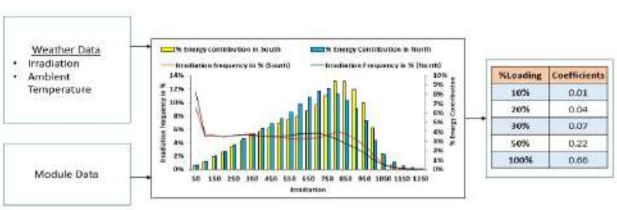

Figure 2. Block diagram of R-program.

IV. RESULT

This program is a shell/black box which will give weighing factors for specific location which are calculated with minute wise irradiation profile while considering effect of temperature too.

This will finally result in output a file which will having new weighing codes will look as:

```
  % Loading Euro  CEC New_Weighing Factor
1        5% 0.03   NA 0.00355324066590436
2       10% 0.06 0.04 0.00902435591295754
3       20% 0.13 0.05 0.0351902132690461
4       30% 0.10 0.12 0.0613580601215881
5       50% 0.48 0.21 0.23138092440958
6       75%   NA 0.53 NA
7      100% 0.20 0.05 0.659493205620924
```

Figure 3. Output result showing new weighing factors.

For finding weighted coefficients for various locations and comparing them with CEC and EURO weighted coefficients, two different location's weather data is being used. This weather data is having yearly data of irradiation and ambient temperature. Source of these data is Meteonorm 7.1. Meteonorm is a database site, having all kind of weather data for almost all locations in world. It is assumed that PV modules/DC section is same for both of the location. Two locations taken are Bap, Rajasthan, India and Hainan, Longyangxiazhen, China. Both are desert area but there is difference in weather condition, one is hot and other is cold. So behaviour of PV module will be different for both locations. Where details of modules are as represented in Table III.

TABLE III. MODULE DETAILS

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

Using R Model new weighted coefficients for bap, Rajasthan, India location as in Table IV

$$Voc = Vstc * (1 + \beta * (Tcell - Tstc)). \tag{5}$$

TABLE IV. WEIGHTED COEFFICIENTS FOR BAP, INDIA

% Loading	New_Euro	New_CEC
5%	0	NA
10%	0.01	0.01
20%	0.04	0.04
30%	0.06	0.06
50%	0.21	0.21
75%	NA	0.52
100%	0.67	0.15

Using same model new weighted coefficients are calculated for Hainan, Longyangxiazhen, China location. The result is displayed in Table V.

TABLE V. WEIGHTED COEFFICIENTS FOR HAINAN, LONGYANGXIAZHEN, CHINA

% Loading	New_Euro	New_CEC
5%	0.01	NA
10%	0.01	0.02
20%	0.05	0.05
30%	0.08	0.08
50%	0.26	0.26
75%	NA	0.37
100%	0.53	0.16

Fig. 4 & 5 represents that different locations are having different weighted coefficients.

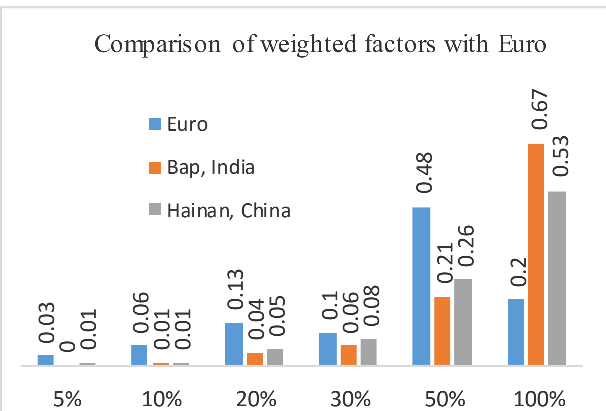

Figure 4. Comparison of weighted factors with Euro.

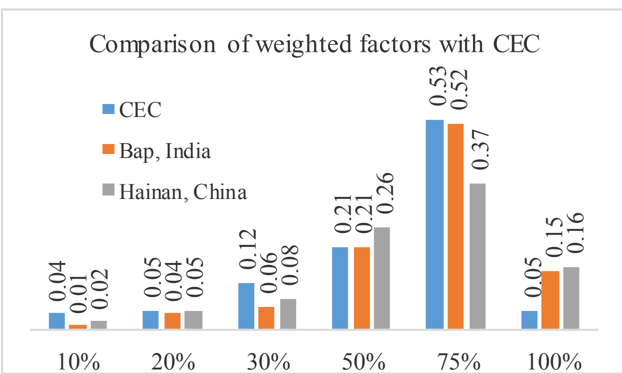

Figure 5. Comparison of weighted factors with CEC.

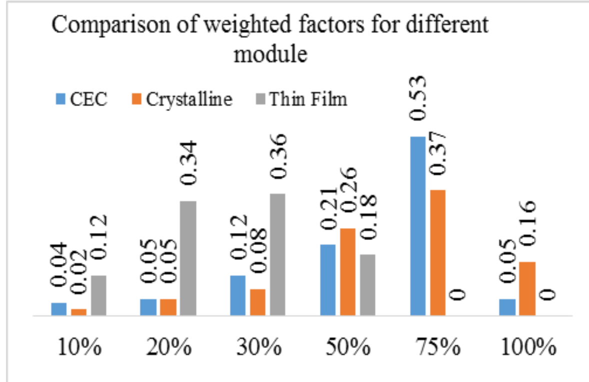

Figure 6. Weighted coefficients for two different modules for same location i.e. Hainan,China.

Fig. 6 shows that for a same location, modules are impacting the weighted conversion efficieny as input to inverter depends upon moduls and temperature coefficients are different for crystalline and thin film modules.

V. CONCLUSION

This program is capable of calculating weighted coefficients for every location. This model's accuracy depends upon user feed data, the accuracy and higher resolution with minimum one year duration data should be the input for accurate weighing factors.

This model is utilizing module data, as this also impacts on weighing factors.

Future scope is to include impact of tracker to minimize error in model. Also it can be connected to a universal database which will directly take new data points with high resolutions to keep updating.

Impact of MPPT technique can be incorporated. Also modules' mismatch losses and inverter's cooling factors can be added to tune this model. This can be used as generation prediction at inverter level also.

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