2016 Second International Conference on Computational Intelligence & Communication Technology

A Comparative Study On Different Types Of PV Modules and Their Optimization for Increasing The Efficiency Part-I

Gayatri Nanda
PG Scholar
School Of Electrical Engg.
KIIT, University

Ritesh Dash
Research Scholar
School Of Electrical Engg.
KIIT, University

Dr. Sarat Chandra Swain
Asso. Prof.
School Of Electrical Engg.
KIIT, University

Dr. Rajesh Kumar
Director (Scientist -F)
NISE, MNRE
Rajesh.kumar66@rediffmail.com

Abstract— **This paper discuss the evaluation of different parameters involved in the solar cell modelling having variable input parameter. The objective of the research was to calculate the most optimized parameters of a solar photovoltaic cell. Solar photovoltaic is the fastest growing industry in the entire world because of its cleanness and easy in handling. The output of the system depends upon the construction and the material used in the system it is because the band gap energy varies for different materials over a wide range. In this paper different types of photovoltaic cells like monocrystalline, polycrystalline, CdTs were investigated to check their feasibility in the practical application of modelling. Additionally comparative analysis of the above materials were given for better understanding of their structure. Experimental analysis were carried out with MATLAB simulation to evaluate their performance.**

Index Terms— **CdTe, insolation, monocrystalline, polycrystalline**

I. Introduction

Highly toxic gas produced from conventional thermal power plant contains carbon dioxide which causes global warming by trapping maximum amount of sun's energy. This affects the sustainability of the system and also creates problem for our future generation. A control over the green house effect can only be reduced by adopting renewable based energy sources instead of conventional method of power generation . However from efficiency point of view green energy is slightly lower as compared to others because of its construction features and types of material used but it can be neglected in comparison to green house gas emission.

India receives approximately 5KWh/m^2/day solar energy for 300 hundred days in a year. It can be used for space heating, thermal energy production etc. Some part of the solar energy can be transferred into useful electrical energy with a solar photovoltaic PV cell. So a solar photovoltaic can make the best use of nature's gift for both thermal energy production and electricity. If all the surface on this earth is covered with solar cell then the amount of energy that can be produced in a single day can mitigate the energy demand of whole world for at least 10 year . Being graced with such a huge amount of energy the complete conversion of the sun energy into effective electricity or heat energy is not possible because of constructional limitation. However effective modelling can increase the efficiency of the solar cell.

Solar photovoltaic cell have under gone many research. Most of the research generally started with either mathematical modelling of the cell either through Matlab or EMTDC. However the Matlab implementation is generally used throughout the world because of easy in implementation and research analysis. Literature says that the photovoltaic cell can be modelled either with single diode model or with two diode model. The basic difference between the two model is the no. of parameter calculation for analysing the cell to calculate the exact loss occurring in the system. These losses may occur either from series or parallel resistance. Actually the series resistance in a cell occurs because of the connecting lid which is used to give power supply from the semiconductor to the external load. In addition to the series resistance there is an another resistance called shunt resistance, which is basically due to the internal resistance of the solar cell and it varies with the different kind of materials used in the manufacturing of the system. So from Matlab design point of view the shunt resistance is generally calculated with iteration method as it is going to affect the system performance a lot.

Gayatri Nanda, PG Scholar School Of Electrical Engg with KIIT University, India, (e-mail: ngayatri02@gmail.com)
Ritesh Dash. Research Scholar School Of Electrical Engg. with KIIT University, India, (e-mail: rdasheee@gmail.com)
Sarat Chandra Swain. Asso. Professor, School Of Electrical Engg. with KIIT University, India, (e-mail: saratswain132@gmail.com)

.

978-1-5090-0210-8/16 $31.00 © 2016 IEEE
DOI 10.1109/CICT.2016.86

IEEE computer society

Different types of solar cell is available in the market like monocrystalline, polycrystalline, CdTe and others. However the monocrystalline and polycrystalline is used because of its efficiency and performance. In this paper all the design is based on the pollycrystalline only as its efficiency lies in between 12 to 16% as compared to 8 to 13% for monocrystalline.

The present paper mainly describes about the modelling of solar PV cell with different types of material to check out the efficiency of the system mathematically and then curve control technique is applied on the present model to find out its real applicability. Paper is organised in the following manner like the second part describes about the solar cell mathematical modelling the third part shows the working environment and the result while the last part shows a comparative analysis among the models.

II. MODELING OF SOLAR PHOTOVOLTAIC CELL

The most fundamental equation with which the mathematical modelling will start is the current equation that describe how the current is generated in the cell and what are the main factors affecting the generated current in the system. So the basic current equation of a solar cell is as follows

$$I=Ip_{h}-Io[exp\ qVnkT-1] \quad (1)$$

Where Iph is the photo generated current or short circuit current that a solar cell can produce at its optimum value. I0 is the current due to the internal recombination of the holes and electrons and is basically varies with the types of materials used. In a two diode modelling there are two nos. of I0 because each diode will represent one current. k is boltzman constant and T is the environmental temperature, which strongly affects the performance of the system. If temperature will increase without solar insolation then it could be a loss for the system and the life span of the cell will also decrease.

For a typical number of applications the cells are usually connected in series and parallel to increase either current or voltage rating of the system so as to make it suitable for application. So in that case the above equation is modified a little more , here the series and parallel resistance are added to the existing equation hence the above equation may be written as follows

$$I=Ip_{h}-Io\ [\exp\ qV/nkT-1]-[V+IRs]/Rsh \quad (2)$$

Or

$$I=Ip_{h}-Io\ \exp\ [V+IRs/nVt-1]-[V+IRs]Rs_{h} \quad (3)$$

As already explained the Iph and I0 represents the photo generated current and regenerative current respectively . Rs and Rsh represents the series and parallel resistance of the system. The thermally generated voltage Vt which is actually due to the internal structure of the cell, because of the series connected cells. For a series connected N nos. of cells the load current can be evaluated as follows

$$I=Ip_{h}-Io\ [\exp\ qV/nkT-1]-[V+IRs]Rs_{h} \quad (4)$$

For a parallel connected solar cell which may contain m nos. of solar cells then the photo generated current will become mIph and that of the intrinsic current may be mI0. So in this way the current rating can be increased to a desired value. With the increase in the cell number the simulation time also increases and therefore a non linear solver may be connected in the system to increase the system calculation and to decrease the seek time.

In addition to the single diode model as shown above many researcher also prefer the two diode model, it is because for calculating the exact loss occurring in the system. However its use is limited because of lots of complex and analysis. It requires either 4 parameter model or 5 parameter model for its calculation.

$$I=Ip_{h}-Io1[\exp(V+IRs)/Nn1Vt-1]-Io2[\exp(V+IRs)/Nn2Vt-1]-[V+IRs]Rs_{h} \quad (5)$$

Here n1 and n2 represents the diode ideality factors of the two diode. The use of series and parallel resistance is quite complex in the analysis of the system it is because series resistance is more common in the voltage source of modelling and shunt resistance is more common in current source of modelling. As the current source of modelling is used universally therefore the shunt resistance may be neglected while designing the system. Both the series and shunt value can be evaluated through iteration procedure however it took a long time to find an optimum value.

A typical data sheet usually contain open circuit voltage, short circuit current, maximum voltage and maximum current. However for predicting the performance these parameters are not sufficient. Therefore in this paper three nos. of points were considered on the characteristic curve , then the corresponding voltage and current were taken for the evaluation of other parameters. An ideality factor of 0.5 and 0.75 were also considered for solving the equation as it is used by most of the researchers for calculation, this is because n1+n2/2>1. Where n1 and n2 is the diode ideality factor in a two diode model. The entire system was tested at STC for the optimum result.

III. SIMULATION AND RESULT ANALYSIS

Sun simulator used to create required sun irradiance and air conditioners for temperature control. Reference cell is connected as shown in figure. For making the performance measurements of the module, a flash pulse is triggered with the simulator on the module, and the irradiance is measured with monitor cell. The module is kept short circuited with the monitor. When the target irradiance level is reached the I-V measurement is initiated. The module is triggered for 2msec of period, during this time the voltage, current and the irradiance of the signal is recorded simultaneously. The measured data is corrected for irradiance and temperature to defined conditions. The system measures 4096 raw data points for each signal.

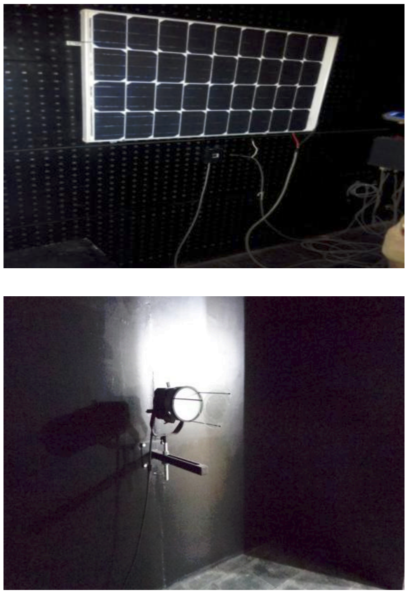

Fig-1:- Sun simulator

NAME	CIGS	A-Si
NUMBER OF CELLS	100	109
AMBIENT TEMPERATURE	25.0	24.9
SENSON TEMPERATURE	24.9	25.2
SHORT CIRCUIT CURRENT(I_{sc})	3.145	1.502
OPEN CIRCUIT VOLTAGE(V_{oc})	58.9	97.6
MAXIMUM CURRENT(I_{mp})	2.709	1.282
MAXIMUM VOLTAGE(V_{mp})	39.2	77.9
F.F	0.574	0.681
CELL EFFICIENCY(%)	11	7.18
MODULE EFFICIENCY(%)	9.81	6.15

Table-1:- STC value of CIGS & A-Si

NAME	CdTe	MONO C-Si
NUMBER OF CELLS	117	36
AMBIENT TEMPERATURE	24.8	25.7
SENSON TEMPERATURE	25.1	25.3
SHORT CIRCUIT CURRENT(I_{sc})	1.087	4.86
OPEN CIRCUIT VOLTAGE(V_{oc})	92.1	22.36
MAXIMUM CURRENT(I_{mp})	0.085	4.56
MAXIMUM VOLTAGE(V_{mp})	58.3	18.25
F.F	0.495	0.765
CELL EFFICIENCY(%)	7.36	17.3
MODULE EFFICIENCY(%)	6.89	14.7

TECHNOLOGY	I_0	V_{oc}	I_{sc}	V_m	I_m
MONO CRYSTALLINE	$2.40*10^{-8}$	22.36	4.86	18.25	4.56
MULTI CRYSTALLINE	$1.20*10^{-7}$	22.06	4.18	17.46	3.87
CdTe	$3.96*10^{-9}$	92.10	1.08	58.30	0.85
A-Si	$1.60*10^{-8}$	97.60	1.50	77.90	1.28
CIGS	$7.37*10^{-8}$	58.89	3.14	39.19	2.70

Table-2:- Parameters at 1000W/m2 of Irradiance

TECHNOLOGY	I_0	V_{oc}	I_{sc}	V_m	I_m
MONO CRYSTALLINE	$2.40*10^{-8}$	22.11	3.88	18.00	3.64
MULTI CRYSTALLINE	$1.20*10^{-7}$	21.79	3.35	17.19	3.09
CdTe	$3.96*10^{-9}$	91.09	0.86	57.29	0.68
A-Si	$1.60*10^{-8}$	96.47	1.20	76.77	1.02
CIGS	$7.37*10^{-8}$	58.18	2.51	38.48	2.16

Table-3:- Parameters at 800W/m2 of Irradiance

TECHNOLOGY	I_0	V_{oc}	I_{sc}	V_m	I_m
MONO CRYSTALLINE	$2.40*10^{-8}$	21.79	2.91	17.68	2.73
MULTI CRYSTALLINE	$1.20*10^{-7}$	21.44	2.51	16.84	2.32
CdTe	$3.96*10^{-9}$	89.79	0.65	55.99	0.51
A-Si	$1.60*10^{-8}$	95.02	0.90	75.32	0.76
CIGS	$7.37*10^{-8}$	57.27	1.88	37.57	1.62

Table-4:- Parameters at 600W/m2 of Irradiance

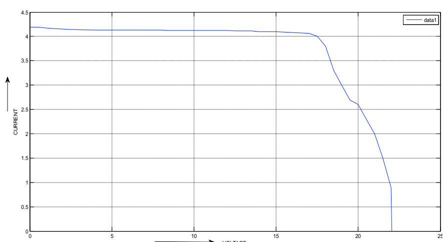

Fig-2:- multicrystaline si

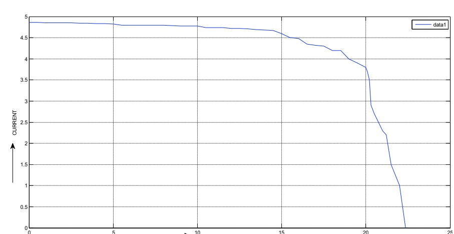

Fig-3:- mono crystaline si

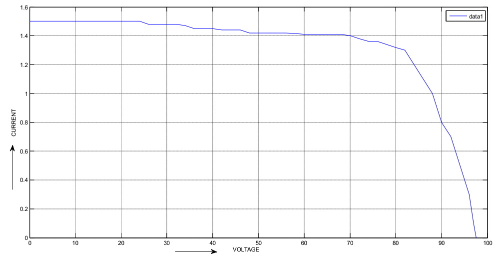

Fig-4:- a-silicon

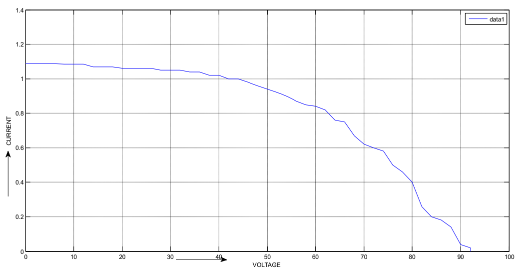

Fig-5:- CdTe

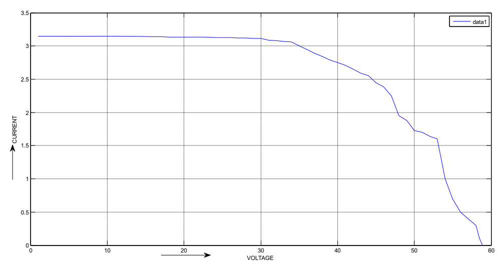

Fig-6:- CIGS

IV. CONCLUSION

The paper presents a solar photovoltaic mathematical modelling implemented using MatLab. Different kinds of materials were tested using the Solar simulator and their result is further used to check the relative similarities between the mathematically evaluated result and the real time tested result. The characteristic curve shows that it is very close to the datasheet value even by considering three number of points at three different location on the characteristic curve. In both the cases the difference is very less and this one diode model can be used as a substitute for testing the material with the data sheet and further calculation.

ACKNOWLEDGEMENT

The authors would like to thank National Institute of Solar Energy under MNRE and the school of electrical Engg. ,Kiit,University for sharing their energy system lab and the support during the experiment .

REFERENCE

[1]. Freijedo, F.D.; Doval-Gandoy, J.; Lopez, O.; Acha, E., "A Generic Open-Loop Algorithm for Three-Phase Grid Voltage/Current Synchronization With Particular Reference to Phase, Frequency, and Amplitude Estimation," *Power Electronics, IEEE Transactions on* , vol.24, no.1, pp.94,107, Jan. 2009

[2]. Feng Wu; Xiao-Ping Zhang; Ping Ju; Sterling, M.J.H., "Modeling and Control of AWS-Based Wave Energy Conversion System Integrated Into Power Grid," *Power Systems, IEEE Transactions on* , vol.23, no.3, pp.1196,1204, Aug. 2008

[3]. Nikkhajoei, H.; Iravani, R., "Dynamic Model and Control of AC–DC–AC Voltage-Sourced Converter System for Distributed Resources," *Power Delivery, IEEE Transactions on* , vol.22, no.2, pp.1169,1178, April 2007

[4]. Rani, B.I.; Ilango, G.S.; Nagamani, C., "A three phase reference current generator for power electronic converters under distorted utility conditions," *Computing, Electronics and Electrical Technologies (ICCEET), 2012 International Conference on* , vol., no., pp.267,272, 21-22 March 2012

[5]. Dash, R.; Behera, P.R.; Ali, S.M., "Hybrid system for meeting global energy demand with solar PV and wind system," *Control, Instrumentation, Communication and Computational Technologies (ICCICCT), 2014 International Conference on* , vol., no., pp.388,392, 10-11 July 2014

[6]. Manojkumar, M.; Porkumaran, K.; Kathirvel, C., "Power electronics interface for hybrid renewable energy system — A survey," *Green Computing Communication and Electrical Engineering (ICGCCEE), 2014 International Conference on* , vol., no., pp.1,9, 6-8 March 2014

[7]. Carrasco, J.M.; Franquelo, L.G.; Bialasiewicz, J.T.; Galvan, E.; Guisado, R.C.P.; Prats, Ma.A.M.; Leon, J.I.; Moreno-Alfonso, N., "Power-Electronic Systems for the Grid Integration of Renewable Energy Sources: A Survey," *Industrial Electronics, IEEE Transactions on* , vol.53, no.4,

[8]. Carrasco, J.M.; Galvan, E.; Portillo, R.; Franquelo, L.G.; Bialasiewicz, J.T., "Power Electronic Systems for the Grid Integration of Wind Turbines," *IEEE Industrial Electronics, IECON 2006 - 32nd Annual Conference on* , vol., no., pp.4182,4188, 6-10 Nov. 2006

[9]. Steimer, P.K., "Enabled by high power electronics - Energy efficiency, renewables and smart grids," *Power Electronics Conference (IPEC), 2010 International* , vol., no., pp.11,15, 21-24 June 2010

[10]. Emanuel, H.; Schellschmidt, M.; Wachtel, S.; Adloff, S., "Power quality measurements of wind energy converters with full-scale converter according to IEC 61400-21," *Electrical Power Quality and Utilisation, 2009. EPQU 2009. 10th International Conference on* , vol., no., pp.1,7, 15-17 Sept. 2009

[11]. Bahrami, S.; Wong, V.W.S.; Jatskevich, J., "Optimal power flow for AC-DC networks," *Smart Grid Communications (SmartGridComm), 2014 IEEE International Conference on* , vol., no., pp.49,54, 3-6 Nov. 2014

[12]. Blaabjerg, F.; Consoli, A.; Ferreira, J.A.; Van Wyk, J.D., "The future of electronic power processing and conversion," *Industry Applications, IEEE Transactions on* , vol.41, no.1, pp.3,8, Jan.-Feb. 2005

[13]. Kelley, J.P.; Wetz, D.A.; Turner, G.K.; Cohen, I., "Integration of pulsed loads into a Microgrid architecture," *Plasma Science (ICOPS), 2013 Abstracts IEEE International Conference on* , vol., no., pp.1,1, 16-21 June 2013