IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.53
Volume 4, Issue 2, February 2024

Boost Converter and MPPT Based Grid Connected Photovoltaic System

Abhishek Kumar[1], Shailesh Kumar[2], Prof.Jagdish Koli[3], Prof. Madhu Upadhayay[4]
Department of Electrical and Electronic Engineering
NRI Institute of Information Science and Technology, Bhopal, India
abhi01101997@gmail.com

Abstract*: In recent years, there has been a significant rise in the popularity of renewable energy sources as a substitute for traditional electrical energy sources. This paper uses MATLAB/SIMULINK to create a 100kW grid-connected solar PV system simulation model. The solar array's performance is influenced by both temperature and solar radiation. Because of the nonlinear characteristics of the system, the power output varies continuously with changing weather conditions. To address this variability, Maximum Power Point Tracking (MPPT) is implemented to monitor and optimize the solar array's output for maximum power.*

Keywords: Photovoltaic (PV), MPPT, Boost Converter, Inverter

I. INTRODUCTION

[1] Introduced a modeling methodology using MATLAB to investigate the repercussions of partial shading on PV array characteristics. Their study emphasizes the significance of accurately replicating partial shading effects and underscores the substantial impact on PV performance. [2] assessed diverse single-diode PV modeling techniques, providing crucial insights for researchers and engineers to select models tailored to their applications, considering precision and computational efficiency. This evaluation is pivotal for making informed decisions in modeling PV systems. [3] proposed a MATLAB-Simulink-based model for PV modules under nonuniform irradiance conditions, offering a more realistic representation of scenarios with varying sunlight conditions. Such models play a vital role in evaluating the performance and reliability of PV systems in dynamic environments. [4] presented a MATLAB/Simulink-based modeling approach specifically for photovoltaic cells, contributing to the understanding of individual cell behavior—an essential aspect in PV system design. This research aids in optimizing the efficiency and performance of PV arrays by focusing on the fundamental unit of photovoltaic systems. [5] suggested a comprehensive framework for modeling and simulating photovoltaic arrays, addressing the need for a holistic approach considering various parameters and dynamic factors. Their work enhances the comprehension of PV array behaviour, facilitating more accurate predictions and improved system design. Concentrating on mitigating the impact of variable shading, the study in [6] addresses challenges that significantly influence the performance of PV systems. Their approach, Sequential ESC, is designed to optimize Maximum Power Point Tracking (MPPT) under varying shading conditions, ensuring optimal extraction of energy. [7] Explored a widely used MPPT algorithm, Incremental Conductance, shedding light on its simulation and practical design aspects. Recognized for its precision and swift tracking capabilities, Incremental Conductance's application was extended in [8] by integrating it with hardware, highlighting its potential in real-world PV systems. [9] Focused on the interface between PV arrays and MPPT controllers, offering insights into the necessary hardware components for efficient MPPT. [10] Provided valuable insights into the characteristics of battery charge controllers in PV systems. [11] Conducted scenario and data analysis to address the main challenges associated with adopting Electric Vehicles (EVs) in India. [12] Emphasized enhancing the robustness and efficiency of PV systems, especially in standalone applications. [13] Explored efficient power conversion and management strategies in standalone PV systems. [14] Investigated the modeling and dynamic interaction of EVs with the distribution grid system. [15] Aimed to maximize the utilization of PV energy sources and reduce dependence on the grid.

IJARSCT

ISSN (Online) 2581-9429

International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)

International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

Impact Factor: 7.53

Volume 4, Issue 2, February 2024

II. DESIGN AND MODELING OF SYSTEM

A. Modelling of solar photovoltaic system

A solar cell is represented by an equivalent model of the current source, diode, series resistance, and load. Several P-N junctions are fabricated in a thin semiconductor wafer and exposed to sunlight, these P- N junctions absorb photons with a higher energy than the band-gap of the semiconductor and produce electron-hole pair. With an external load connected to the PV panel, a direct current (also known as Photocurrent) flows through it to balance out the number of holes and electrons in the semiconductor. An equivalent circuit for a PV solar cell can be presented with a constant current source, a P-N junction diode, a series, and a shunt resistor (fig 1).

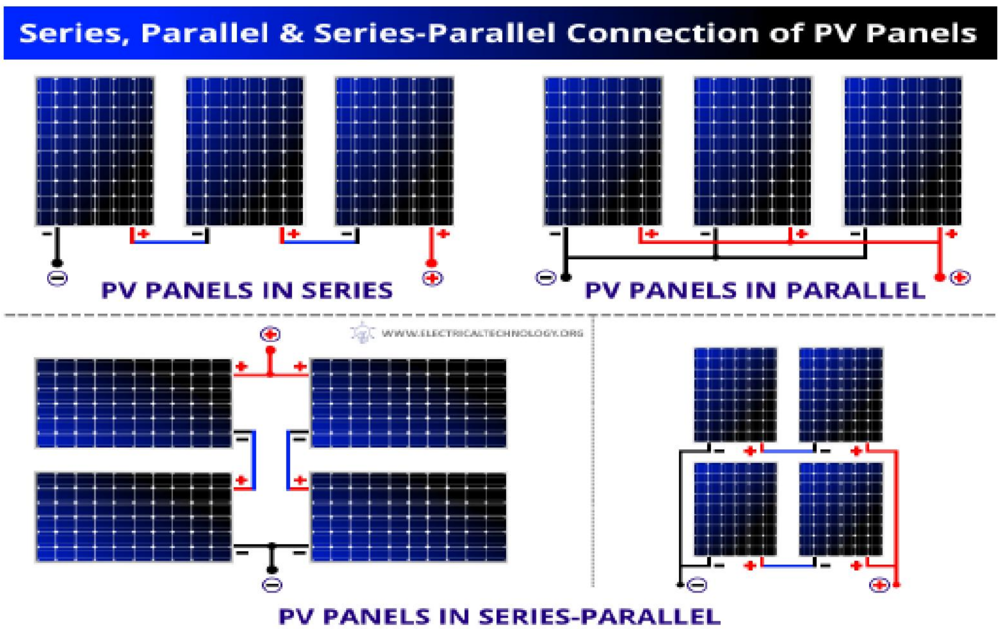

Fig.1 Electrical configurations of solar cells

$$I = I_{PV} - I_O\left[\exp\left(\frac{V + IR_S}{aV_T}\right) - 1\right] - \left(\frac{V + IR_S}{R_P}\right) \quad (1)$$

The open-circuit voltage, generally denoted as V_{OC}.

$$V_{OC} = \eta \cdot V_T \cdot \ln\left(\frac{I_f}{I_0} + 1\right);\ V_T = \frac{K \cdot T_{cell}}{q} \quad (2)$$

B. Boost Converter

DC-DC converters are versatile electrical circuits that can adjust voltage levels in DC systems. They can step up (boost), step down (buck), or perform both functions (buck-boost) as needed. One of the most critical factors that permits voltage management is the duty ratio, which regulates the converter's on-off time of a switch

Boost Converter: This kind is appropriate for circumstances when you need to step up the voltage, like charging batteries, because it raises the output voltage level relative to the input voltage.

C. Maximum Power Point Tracking

MPPT is an algorithm that forces the point of operation of the panel to be at the MPP. The perturb&Observe algorithm, which is the most used MPPT algorithm, uses a simple feedback arrangement and a few measured parameters (specifically V and I of the PV panel)

III. RESULT AND DISCUSSION

A photovoltaic system with a capacity of 100 kilowatts is linked to the 25-kilovolt grid using a 3-phase, 3-level Voltage Source Converter (VSC) with a boost converter shown in fig3. The Maximum Power Point (MPP) controller inutilizes the Perturb and Observe (P&O) algorithm. When exposed to 1000 watts per square meter of solar radiation, the solar array can produce up to 100 kilowatts of power. The voltage generated by the solar array increases from 5 kHz and reaches the boost converter, which converts the initial 273 volts DC from the photovoltaic (PV) system to 500 volts DC. Through the P&O algorithm, the MPPT controller adjusts the switching duty cycle to maximize electrical energy extraction from the photovoltaic system. The MPPT system further adjusts the duty cycle to meet the required voltage for the 1980 Hz 3-phase, 3-level VSC. This VSC maintains a unity power factor while converting the 500-volt DC input to a 260-volt AC output. The VSC control system has two control loops: an inner loop regulating the P and Q current components (grid Iq and Id currents), and an outer control loop adjusting the DC link voltage within a range of plus or minus 250 volts.

The output of the external DC voltage controller determines the reference current for Id. To maintain a unity power factor, this sets the reference current for Iq to zero. The voltage controller outputs, V_d and $V_{q,}$ are then used to generate three modulated signals. The PWM generator utilizes these signals with a reference to$_{Uabc.}$

TABLE -1

Parallel strings	66
Series connected modules per string	5
Cells per module	96
P_m (W)	305.226
V_{oc} (V)	64.2
I_{sc} (A)	5.96
V_{mp} (V)	54.7
I_{mp} (A)	5.58

Fig.2 shows10-kvar bank is utilized to filter out harmonics generated by the VSC. A three-phase connection transformer with a rating of 100 kVA is employed to convert between 260V and 25 KV, facilitating connection to the utility grid. The utility grid operates at a transmission level comparable to 120 KV and a 25 KV distribution feeder.

.

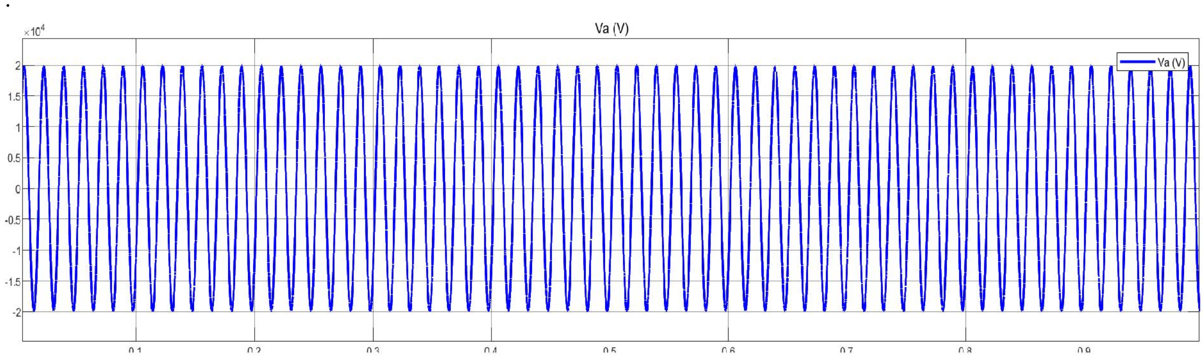

Fig.2 Grid Voltage Waveform

IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.53
Volume 4, Issue 2, February 2024

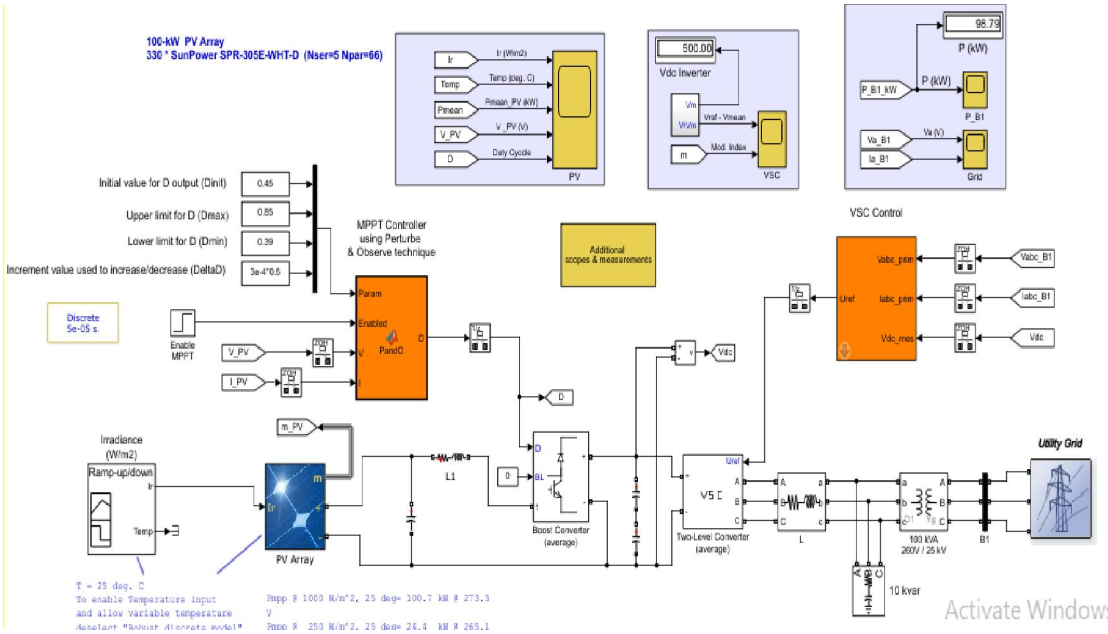

Fig. 3 Simulation model of 100 Kw PV system with grid-connected using a converter

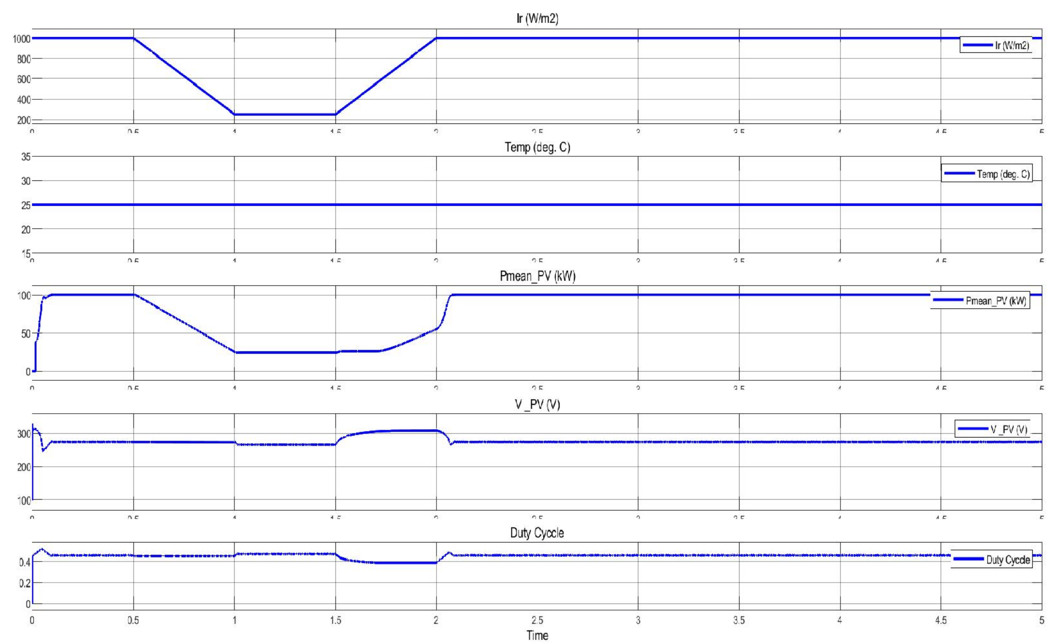

Fig. 4 PV Panel waveform (a)Irradiation (b) Temperature (c) Power (d) Panel voltage (e) Duty Cycle

The PV array consists of 330 SunPower modules, which collectively generate 100 KW of power. These modules are arranged in 66 strings, with each string comprising five series-connected modules that are connected in parallel. This configuration results in a total power output of 100.7 KW. Each individual module, according to the manufacturer's specifications, contains 96 series-connected cells and exhibits the following characteristics Voc of 64.2 volts, Isc of 5.96 amperes, and at maximum power, Imp of 5.58 amperes and Vmp of 54.7 volts

In Fig 4, The simulation begins with the use of standard test settings, where the temperature is 25 degrees Celsius, and the solar irradiance is set to 1000 watts per square meter (W/m²). Between t=0.05 seconds and t=0 seconds, the pulses sent to both the VSC and the Boost converters are halted. During this period, the PV voltage equals the open-circuit voltage, calculated as the product of the number of N_{ser} and the $V_{oc,}$ resulting in a value of 321 volts. capacitor is charged 500 volts, and the three-level bridge in the system functions as a diode rectifier. At t=0.05 seconds, the VSC and Boost converters are re-activated. The regulation voltage for the DC link is set at V_{dc}=500 volts. The D for the boost converter is fixed at 0.5, as indicated on the PV scope. By t=0.25 seconds, the system has reached a steady state. The PV voltage (V_PV) is calculated as (1-D) times Vdc, resulting in (1-0.5)*500 = 250 volts, as observed in the $V_m$trace on the PV scope. The solar array's initial P_0 is 96 kilowatts, while the Pmax under 1000 W/m² irradiation conditions is 100.7 kilowatts. The voltage and current in phase A at the 25-KV bus are in phase according to the grid's scope. The MPPT system is activated at t=0.4 seconds.

Fig .5 and fig 6 shows , P_{max}, the MPPT controller initially adjusts the solar voltage by modifying the duty cycle. When the duty cycle D is set to 0.454, it achieves Pmax at 100.4 KW. The specifications of the solar module, calculated as the product of the number of Nser and the Vmp, indicate that the mean voltage of the PV array at t=0.6 seconds will be approximately 274 volts. Meanwhile, the solar irradiance gradually decreases from 1000 W/m² to 250 W/m² between t=0.6 and t=1.1 seconds. Throughout this period, the MPPT system continuously tracks and maintains the Pm By t=1.2 seconds; when the irradiance has fallen to 250 W/m², the duty cycle is adjusted to D=0.461, resulting in a PV Vm=268 volts and an associated power output of Pm=24.3 kilowatts. The MPPT's effective tracking of the maximum power during this rapid change in illumination conditions is worth noting.

To investigate the effect of temperature increase, the solar irradiance is maintained at 1000 W/m² between t=1.2 and t=2.5 seconds, after which the temperature is raised to 50 degrees Celsius. It should be noted that as the temperature increases from 25 ^{0}C to 50 ^{0}C , the output power of the PV array decreases from 100.7 KW to 93 KW.

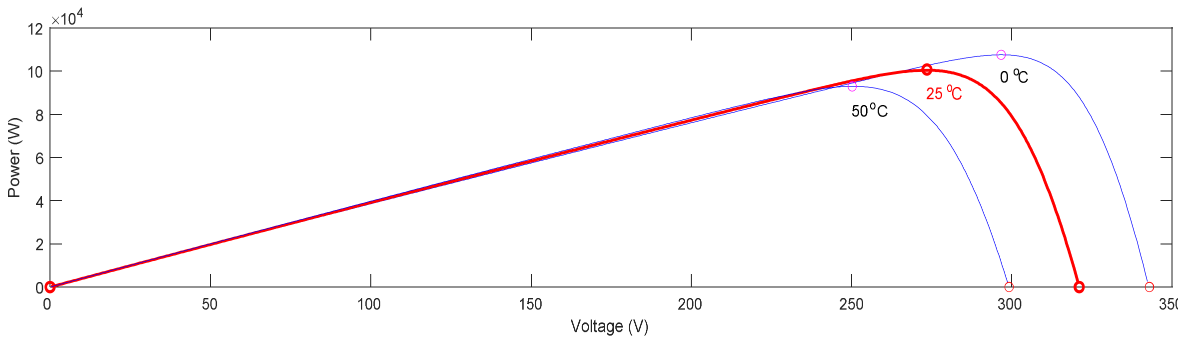

Fig. 5 P-V Array at 1000 w/m2 irradiation and different temperatures

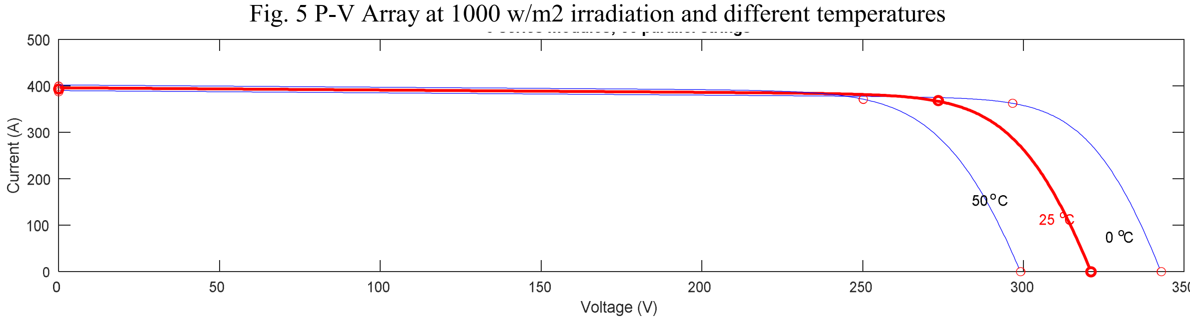

Fig. 6 V-I at 1000 w/m^2 irradiation and different temperatures

IV. CONCLUSION

In this paper, the various waveforms generated during the simulation, serve as evidence of the successful MPPT results. In comparison to a more detailed model, this simplified model offers a significant advantage in terms of speed and efficiency. Additionally, we examined the performance of Perturb and Observed MPPT controllers under varying irradiance conditions. Notably, it becomes evident that this type of MPPT controller is most effective when irradiance levels remain relatively constant. In the paper, our aim was to design an efficient and cost-effective solar PV power generation system, and we accomplished this objective using MATLAB software.

Future endeavors in this field can explore different Maximum Power Point Tracking (MPPT) methods and modified algorithms to enhance efficiency, particularly in rapidly changing environmental conditions. There's potential for designing a more compact and cost-effective model for solar PV systems, with reduced operating and maintenance expenses to make it more appealing to users.

REFERENCES

[1]. Patel, Hemant, Anurag Kumar, Aashish Kumar Bohre, and Omkar Yadav. "Reliability Based Performance Analysis of Distribution Network with Dispersed Generation Using Optimization." In 2023 3rd International Conference on Energy, Power and Electrical Engineering (EPEE), pp. 982-988. IEEE, 2023.

[2]. H. Patel, B. K. Saw, A. K. Bohre and O. Yadav, "Analyze the Impact of Distributed Generation Units on Distribution System Performances," 2023 IEEE International Conference on Power Electronics, Smart Grid, and Renewable Energy (PESGRE), Trivandrum, India, 2023, pp. 1-6.

[3]. Patel, Hiren, and Vivek Agarwal. "MATLAB-based modeling to study the effects of partial shading on PV array characteristics." IEEE Transactions on Energy Conversion 23, no. 1 (2018): 302-310.

[4]. Shongwe, Samkeliso, and Moin Hanif. "Comparative analysis of different single-diode PV modeling methods." IEEE Journal of Photovoltaics 5, no. 3 (2021): 938-946.

[5]. Ding, Kun, XinGao Bian, HaiHao Liu, and Tao Peng. "A MATLAB-simulink-based PV module model and its application under conditions of nonuniform irradiance." IEEE Transactions on Energy Conversion 27, no. 4 (2022): 864-872.

[6]. Salmi, Tarak, Mounir Bouzguenda, Adel Gastli, and Ahmed Masmoudi. "Matlab/Simulink based modeling of a photovoltaic cell." International journal of renewable energy research 2, no. 2 (2012): 213-218.

[7]. Villalva, Marcelo Gradella, Jonas Rafael Gazoli, and Ernesto Ruppert Filho. "Comprehensive approach to modeling and simulation of photovoltaic arrays." IEEE Transactions on Power Electronics 24, no. 5 (2009): 1198-1208. F. Wang, X. Wu, Z. Wang, "Analysis of unified output MPPT Control in subpanel of PV converter system", IEEE Transaction on power electronics, vol.-29, no. 3, pp. 1275- 1284,.

[8]. P. Lei, Y. Li, Seem, "Sequential ESC-Based Global MPPT Control for Photovoltaic Array with Variable Shading", IEEE Transaction on Sustainable Energy, vol.-2, no. 3, pp. 348-358, April, 2011.

[9]. Z. Xuesong, S. Daichun, M. Youjie, C. Deshu, "The simulation and design for MPPT of PV system based on Incremental conductance method," Wase International Conference on information engineering, 2010.

[10]. A. Safari, S.Mekhilef, "Simulation and Hardware Implementation of Incremental Conductance MPPT with Direct Control Method Using Cuk Converter," IEEE transaction on Industrial Electronics, vol. 58, no. 4, pp. 1154-1161, April, 2011.

[11]. W. Xiao, N. Ozog, W. G. Dunford, "Topology Study of Photovoltaic Interface for Maximum Power Point Tracking,",IEEE Transactions on Industrial Electronics, vol. 54, no. 3, June, 2007.

[12]. S. Harrington, J. Dunlop, "Battery charge controller characteristics in Photovoltaic systems", IEEE, Aerospace and Electronic Systems Magazine,vol.-7, no. 8, pp. 15-21, August,1992

[13]. M. Gengaraj, J. Gnanachandran, "Modeling of a standalone photovoltaic system with charge controller for battery energy storage system," International Journal of Electrical Engineering, vol.6, no. 3, pp. 78-81, 2013.

[14]. R. Gules, J. Pacheco, "Maximum power point tracking system with Parallel connection for PV stand-alone application," IEEE transaction on industrial electronics, vol.55, no.7, pp. 2674-2683,July, 2008

[15]. Z. Liao, X. Ruan, "Control strategy of bi-directional dc-dc converter for a novel standalone photovoltaic power system," IEEE vehicle power and propulsion conference (VPPC),pp. 1-6, September, 2008.