Design and Optimize Solar Panel Energy by Extraction Dynamically Adjusting Voltage and Current to Match Battery's Need

Kanchan Vaidya, Ankush Kadu, Sakshi S. Patil, Vishakha V. Shende, Saurav A. Dhokchaule, Shrivallabh B. Borude
Department of Electronics & Telecommunication Engineering, Ajeenkya DYPSOE, Pune, India

ABSTRACT

Sun based vitality request has risen within the final decade due to upgraded vitality necessities and exhaustion of non-renewable assets; in any case, the foremost noteworthy issue with sun oriented imperativeness is its insecurity, which depends on climatic conditions like temperature and sun fuelled light. To diminish this issue, a battery is routinely put between the stack and sun based board as a back source of control. The sun based cell voltage is direct affected by the concentrated of sunshine, and tall voltage causes pulverization of batteries. Most unmistakable Control Point Taking after (MPPT) technique is utilized in organizes to maximize photovoltaic (PV) module control and keep up a critical allocated from cheating of the batteries. The MPPT charge controller plays two major parts: battery security and imperativeness abdicate checking. The nuts and bolts of coordinate current (DC) vitality meter and most extreme control point following based sun oriented charge controller are investigated in this ponder.

Keywords
DC-DC Converter, Energy optimization, Maximum power point tracking (MPPT), photovoltaic (PV) systems, Renewable energy, Solar charge controller.

I. INTRODUCTION

Sun powered control is an operable source of vitality inside a span of time that's not exceptionally remote. For the collection and conversion of solar radiation into electrical energy, photovoltaic (PV) panels are integrated with both series and parallel arrangements. Regularly, PV clusters which exchange daylight as direct-current (DC) power from an disconnected PV framework. It also comprises charge controller which views the batteries' charging as it is charged or otherwise. Being a critical component in PV systems, the charge controller guarantees that the batteries receive the appropriate charging voltage. There's progressing examine in various collection techniques, such as concentric collectors and thin-film contraptions, due to the uneven transport of sun based imperativeness. In this specialized paper, the authors looked at how a PV sun based board works. The First exceptional Control Point Tracker (MPPT), a control electronic contraption that the authors utilize, essentially advances the productivity of the system. The framework is working at its greatest control point (MPPT) all the time due to the application of this innovation. The most extreme sum of control was exchanged through this strategy. A sun based array enhances an MPPT's productivity whereas diminishing the fetched of the whole framework concurrently. [1]

Other than, the authors utilized a DC-DC converter for its execution the "Annoy and Watch" calculation to plan MPPT. The authors distinguished that the "BUCK" converter would suit the plan most after a comparison of a run of DC-DC converters. There's a point on each sun based cell at which most extraordinary control is passed on by the union of its voltage V and current I yields. The ―maximum control point‖ is outlined in Fig. 1, which is the surrender made by the sun fuelled cell [2]

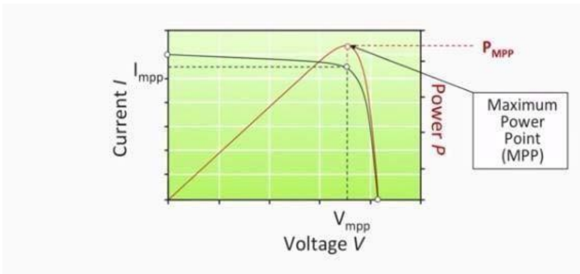

Fig.1 MPPTIVversusPVCurve

The buck converter functions were solar cell at which maximum power is delivered by the union of its ‗voltage (V)' and ‗current (I)' outputs. The ―maximum power point‖ is demonstrated in Fig. 1, which is the output produced by the solar cell. [3]

The buck converter functions were regulated by a Raspberry Pi Pico microcontroller. The program executes an algorithm based on the voltage and current sensor values and sends them to the Arduino to control the PWM duty cycles. A high-efficiency charger controller must be employed to achieve maximum efficiency of overall solar-PV run system and microcontroller ensures that charger controller operates efficiently. [4]

II. Major COMPONENTS

A. Solar Panel

To achieve the demanded output power under normal condition. Solar panel is built by series and parallel arrangement of a set of solar cells. Proteus try to perform better than solar cell in its equivalent circuit while being designed.

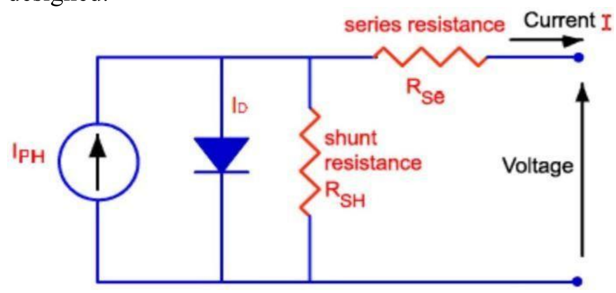

Fig. 2 Equivalent circuits of solar cell

Consider the above Fig.2, Apply the node equation at the

Junction where

The diodes IPH, RSE, and RSH converge. The following is an expression for the present equation:

$$I = I_L - I_0 \left\{ \exp\left[\frac{q(V + IR_S)}{nkT}\right] - 1 \right\} - \frac{V + IR_S}{R_{SH}}. \quad (1)$$

TABLE I. SOLAR PANEL SPECIFICATIONS

Maximum Power Pm	50 W
Voltage at Maximum Power (V_{MP})	17.2 V
Current at Maximum Power (I_{MP})	2.90 A
Open Circuit Voltage (Voc)	21.5 V
Short Circuit Current (Isc)	3.16 A

To get the desired output, 36 solar cells are used in total. Proteus ISIS was used to implement the design, as seen below:

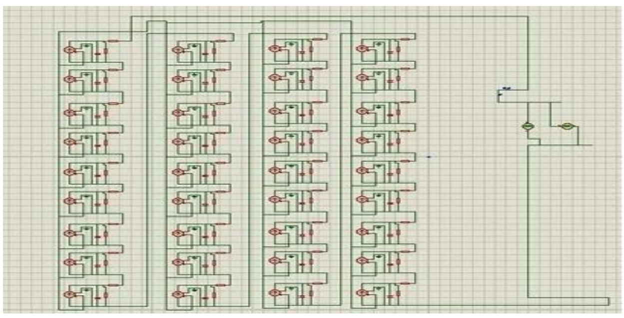

Fig. 3 Solar Panel Design on Proteus

B. DC-DC Buck Converter

One of the DC-DC converters whose output voltage is lesser than and equal to its input voltage is a buck converter. In the given project, switching of the MOSFET has been done with the help of a raspberry pi and the value of the capacitor and inductor used therein matters when the authors design the buck converter. It's an essential step because such variables play an influential role on the efficiency of the converter. Taking it for granted that the solar panel works at maximum capacity, the inductance and capacitance values were calculated and resulted in an inductance value of L=33µH and a capacitance value of C=220µF [3].

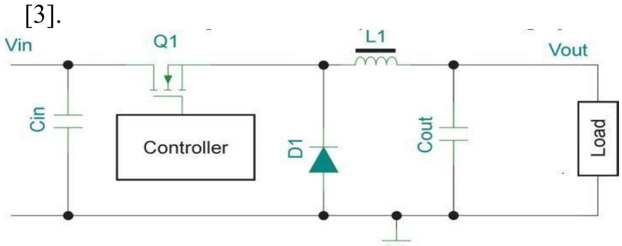

Fig. 4 Buck converter

C. Raspberry Pi Pico

The Raspberry Pi Pico is an embedded version of a small device with an integrated USB interface that is intended for surface mounting on a breadboard, which makes it very versatile. Its small size belies its extensive capabilities; as it is fully compatible with breadboards. Pico has all of the features of the Arduino Nano, but it has a greater number of GPIO pins when evaluated electrically. It has an onboard 3.3V jumper, but no power jack, and it automatically detects and switches to a higher -voltage power source without the need for a power- select jumper. The Raspberry Pi Pico has a footprint comparable to other microcontrollers, which allows for more breadboard space, featuring extra Power and Ground pins on one side and TX, RX, GND, and power pins on the other. The RP2040 chip, which offers more processing and data memory capacity, has been included in the revised version. The two layers of the design allow affordability and ease of change.

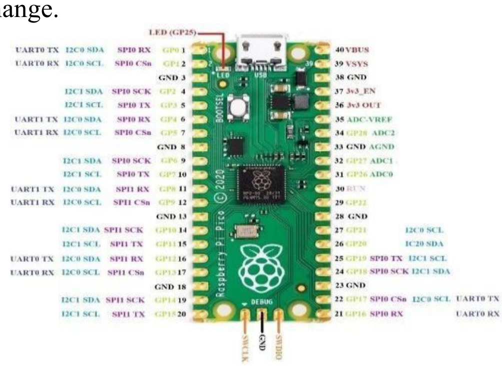

Fig 5 Raspberry Pi Pico Pin Configuration

III. METHODOLOGY

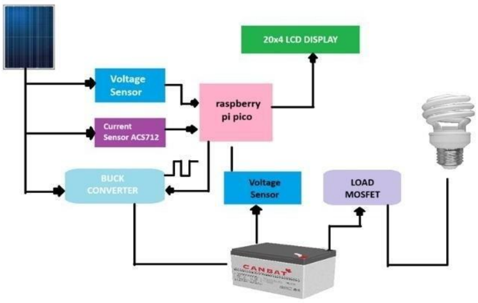

Fig. 6 Block Diagram

The Raspberry Pi Pico microcontroller is indicated in this block diagram as the system's core component. Voltage and current sensors were provided input from the solar panel. Both voltage and current are monitored by the microcontroller, and the data is displayed on LCD panel. It gives an output of a PWM signal to the buck converter, which determines whether or not to switch on the solar panel to the battery for charging it depending on the power it has detected. Depending on the battery level, as indicated by the voltage sensor and bolstered back to microcontroller, the stack MOSFET is signaled by the microcontroller to put through or disengage the stack from the battery

IV. PERTURB AND OBSERVE METHOD

Control yield is evaluated by Irritate and Watch strategy by changing the cluster voltage, which is controlled by the framework in little sums Alterations are made so also on the off chance that the control yield increments until it now not increments. Bother and Observe is the term utilized for this handle and the procedure is still one of the preeminent well known, in show disdain toward of the reality that it may cause more control abdicate swings. This calculation moreover calls itself After you've passed the most elevated point (after the crest of the slope), the control starts to decrease, so the calculation "chooses" to stopped or alter gears. At times, the Chafe and Observe calculation tunes the surrender terminal of the sun cell a few time as of late comparing the control gotten inside the current cycle to the control of the past cycle. Working point can have come near to MPP In case the control is more vital than the past one, at that point the working point can be near MPPT. The operating point must be near the MPPT with some extra voltage perturbations in the same direction. In this manner, the working point strays from Greatest Control Point (MPP) in the event that control drops, something else, and the heading of annoyance must be turned around to urge back to the MPPT.

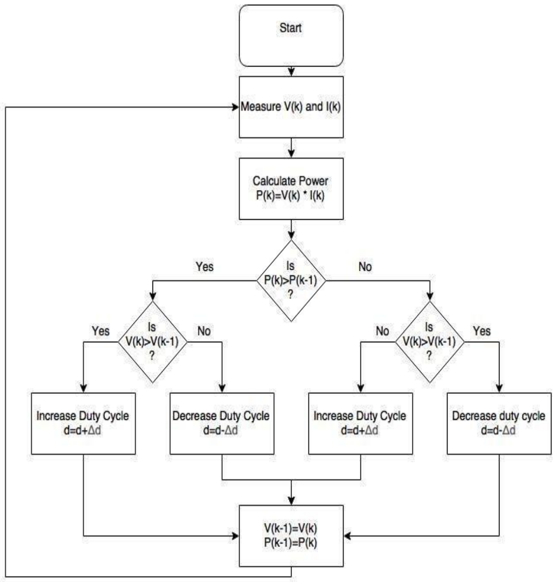

Fig. 7 MPPT Algorithm

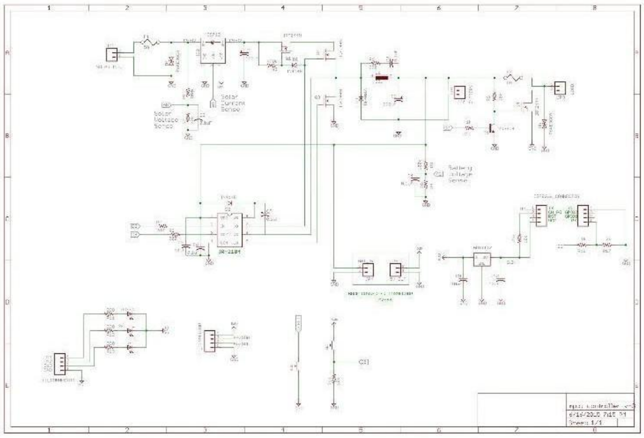

Fig.8 Complete Circuit Diagram

Figure 8 is schematic of the MPPT solar charge controller, which has been designed and depicts all interfacing between main components of project.

V. SIMULATION OF BUCK CONVERTER

A. Buck Converter Simulation Input Data:

Figure 9 is the simulation of a buck converter in MATLAB.

The specifications are stated below: Input Voltage = 12V, Duty Cycle = 25%, Frequency = 25 KHz, Inductance = 80µH, Capacitance = 20 µF, 20V.

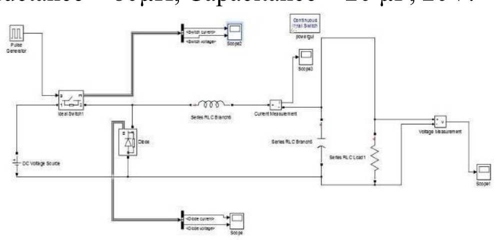

Fig. 9 Simulation of Buck Converter in MATLAB

The buck converter output behaviour is illustrated in Fig. 10. The major part of the buck converter is to diminish the DC voltage from the reference voltage of 12V to the yield voltage of 3V. As it can be observed in Fig. 10, the yellow filled run is the crest voltage of 3V when utilizing the buck converter with an input voltage of 12V.

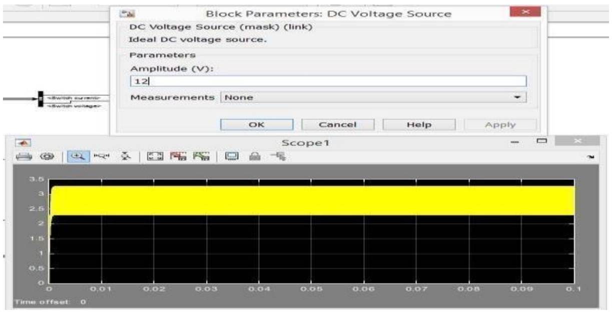

Fig. 10 Output Voltage of Buck Converter

VI. HARDWARE PROTOTYP

Several electronic components with values that were verified and tested by the simulation process were used to construct a hardware prototype. The results were shown on an LCD panel. The outcomes of hardware implementation are displayed in the observations that follow.

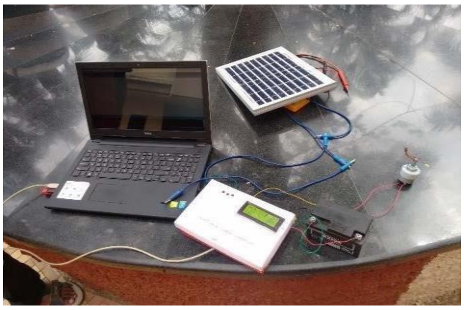

Fig. 11 Hardware Prototype

VII. OBSERVATIONS

A. Charge Controller:

Figure 12 shows the demonstration of the charge controller. Both columns describe the process in which either a load or a battery is turned on.

Sr No.	Conditions	Results Expected	Output Observed
1.	Battery volt >10v Solar power>1w	Load ON Battery Charging OFF	SOL 18.01V 0.25A 4.42W BAT 10.46V off PWM 67% Load on
2.	Battery volt <10v Solar power<1w	Load OFF Battery Charging ON	[illegible]

Fig. 12 Charge Controller Demonstration

The beginning level line appears that when the sun arranged control is over 1W and the battery voltage is over 10V, the total supply is given to the stack to turn it on and deplete the battery. Agreeing to the moment flat push, when the battery voltage falls underneath 10V and the sun powered control is underneath 1W, charging of the battery happens and the stack remains off. Other than, on the off chance that sun fueled control is less than 1W and the voltage of the battery is less than 10V, the stack is off charging the battery.

B. Duty Cycle:

Sr No	V_{in} (v)	I_{in} (A)	R_i (Ω)	R_L (Ω)	Duty cycle (Calculated) (%)	Duty cycle (Observed) (%)
1.	13.8	0.34	40.58	67	64	SOL 13.80V 0.34A 4.69W BAT 10.23V on PWM 68% Load on
2.	12.73	0.4	31.8	67	75	SOL 12.73V 0.40A 5.60W BAT 10.29V on PWM 75% Load on
3.	14.2	0.49	28.98	67	79	SOL 14.20V 0.49A 6.80W BAT 10.31V on PWM 80% Load on

Fig. 13 Duty Cycle Observations

The input impedance $R\ i$ must match the load impedance $R\ L$ in order to get optimal power. However, it is impossible to maintain a constant input resistance $R\ i$ due to the constant fluctuations in the input voltage. For this reason, the Duty Cycle is worked on in order to obtain $R\ i = R\ l$ according to the algorithm. The input impedance has the origin at

$$Ri = \eta\ RL/d^2 \qquad (2)$$

The MPPT bend was effectively charted at distinctive times of the day. The P-V curve was graphed with the resistive load characteristics, where the ―maximum power point‖ is marked. The charge controller performance was effectively demonstrated as stated in the observations.

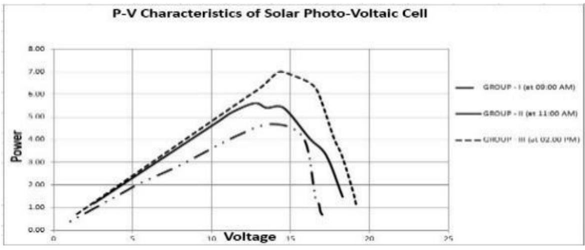

Fig. 14 P-V Characteristics of Photo Voltaic Cell

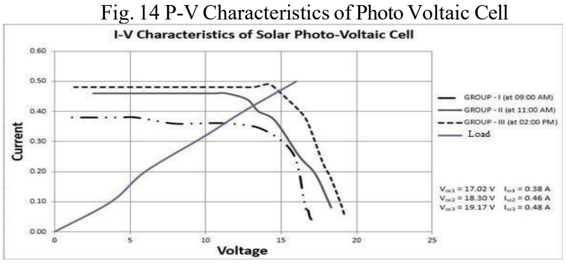

Fig. 15 I-V Characteristics of solar cell

Here, Ri= Input Impedance RL = Load Impedance
Ƞ = Efficiency n = Duty Cycle
Here, it is taken that the Efficiency of the panel is 25%.

VIII. RESULT

The experimental and simulation results demonstrate that the MPPT controller effectively tracks the maximum power point under varying irradiance conditions. The buck converter maintains a regulated output voltage, thereby preventing battery overcharging and improving overall system efficiency compared to conventional solar charging methods.

IX. CONCLUSION

The designed MPPT-based solar charge controller successfully enhances solar energy utilization and ensures reliable battery protection. The system performance has been validated through simulation and hardware observations. Future scope includes implementation of advanced MPPT techniques, integration with IoT-based monitoring, and large-scale field deployment for performance evaluation.

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XI. REFRENCES

[1] A.S.M. Jiaul Hoque1*, Sheik Md. Kazi Nazrul Islam1, 2, Md. Abubakar Siddik1, Sabbir Ahamed1,‖Design and Implementation of a Microcontroller Based 12V-7A/10A Smart Solar Battery Charge Controller‖.

[2] Marcelo Gradella Villalva, Jonas Rafael Gazoli, Ernesto Ruppert Filho, "Analysis and simulation of the P&O MPPT algorithm using a linearized PV array model,‖ 10th Brazilian Power Electronics Conference (COBEP), Brazil, September 27 - October 1, 2009.

[3] Muhammad H. Rashid, "Power Electronics: Circuits, Devices Applications" Text Book.

[4] Dr.Anil S. Hiwale, Mugdha V. Patil, Hemangi Vinchurkar,‖An Efficient MPPT Solar Charge Controller‖, International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering Vol. 3, Issue 07, July 2004

[5] Thesis "Maximum Power Point Tracking: Algorithm and Software Development", Delft University of Technology Faculty of EEMCS June 27, 2012

[6] D. K. Sharma, Purohit G, ―Advanced Perturbation and Observation (P&O) based Maximum Power Point

[7] Tracking (MPPT) of a Solar Photo-Voltaic System‖, 5th International Conference on Power Electronics, India, 6- 8 December, 2012.

[8] Richard J. Comp, "Practical Photovoltaics: Electricity from Solar Cells", 2nd edition (pp.15-17), 2011.

[9] Nur Mohammed, Muhammad Quanruzzanan, Mohammad Rubaiyat, ―Parasitic effects on the performance of Dc-Dc SEPIC in Photovoltaic MPPT Applications‖.