AN EFFICIENT DIRECT MPPT FOR PV SYSTEM UNDER EXTREMELY FAST CHANGING IRRADIANCE

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ABSTRACT—

Photovoltaic cells require of Maximum Power Point Tracking (MPPT) algorithms to ensure the amount of power extracted is maximized. True seeking, direct duty cycle control MPPT algorithms are a simple and straightforward solution that can provide high tracking efficiency. In these algorithms the duty cycle is traditionally modified to reach a new steady state prior performing a new MPPT iteration. Therefore, the MPPT update period must be larger than the converter's settling time to reach a new steady state, which limits the dynamic tracking performance. This work proposes a novel direct duty cycle control method that does not require the converter to achieve steady state in between MPPT updates. The proposed method benefits from the natural oscillations occurring in the converter to obtain extreme dynamic tracking improvements while maintaining simple implementation with no need of employing temperature or irradiance sensors. The scheme being introduced combines MPPT concepts with large-signal geometric control to achieve a reliable, high-performance solution very suitable for applications with rapidly changing irradiance such as wearable technology and rooftop EV. The theoretical analysis is supported by detailed mathematical procedures and validated by simulations and experimental results.

I. INTRODUCTION

Photovoltaic (PV) cells are one of the most popular renewable energy sources with a Compound Annual Growth Rate (CAGR) of 42% from 2000 to 2015 [1]. Growth is expected to continue, resulting in a cumulative global installed capacity of 613GW by 2020 [2]. Battery chargers and grid-tied applications are amongst the most common targets for PV applications. However, the popularity of alternative applications, such as manned [3, 4] and unmanned vehicles [5, 6], and wearable technology [7, 8], is increasing. Maximum Power Point Tracking (MPPT) algorithms must be employed to maximize the power transfer from the solar panel to the load. The MPPT algorithm must be implemented at the first stage of the energy conversion chain, where DCDC converters are undoubtedly the most popular choice.

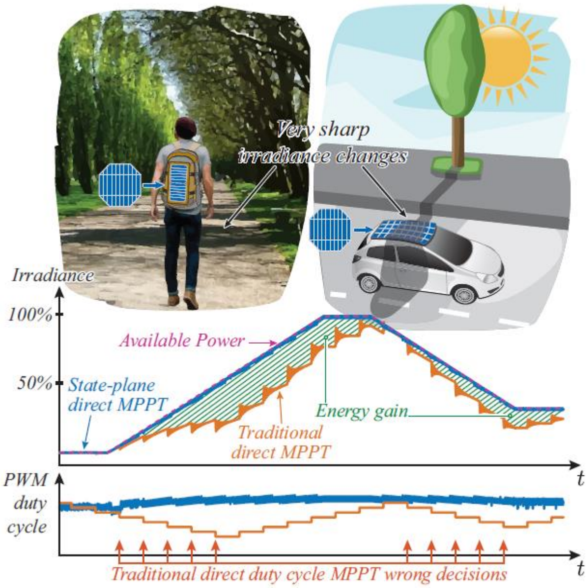


Fig. 1. PV applications with fast irradiance changes (e.g. backpack or car mounted PV) require extreme dynamic performance in order to avoid wrong MPPT decisions and maximize the energy extracted.

MPPT techniques with degrees of accuracy and complexity have been proposed [9, 10]. Hill-climbing techniques, such as Incremental Conductance (IC) and Perturb and Observe (P&O), are a very popular alternative due to their flexibility and balance between complexity and accuracy. High tracking efficiency (fraction of electrical energy absorbed as percentage of the total available) can be achieved by employing these algorithms in static applications where irradiance and temperature change slowly. However, the traditional implementation of these algorithms under rapidly changing environmental conditions is especially prone to errors, leading to lower extraction efficiencies [11, 12]. Examples of rapidly changing environmental conditions are shown in Fig. 1. The fast sunshine-to-shade sudden irradiance transient found in moving PV applications lead to wrong decisions in the traditional hill-climbing method.

This work proposes a novel theoretical framework based on state-plane modelling of the power converter. The analysis results in a new method of operating direct MPPT algorithms to enable extreme dynamic tracking improvements while maintaining simple implementation with no requirement of temperature or irradiance sensing. State-plane modelling of the basic PWM-based DC-DC topologies, showing fast and predictable transient response, large-signal reliable operation, and reduced reactive components size. By employing state-plane analysis of the dynamic behavior of the converter, the necessity of reaching steady state before performing a new MPPT iteration is eliminated. In this way, no fixed set-point is required and the control law continuously leads the operating point to the MPP achieving a dynamic solution to solve the dynamic MPPT problem.

II. RELATED WORK

Abdelhamid et.al., (2014) presents an overview of different commercial photovoltaic (PV) module options to power on-board electric vehicles (EVs).We propose the evaluation factors, constraints, and the decision-making criteria necessary to assess the suitability of this PV module for this application. The incorporation of quality function deployment (QFD) and the analytical hierarchy process (AHP) is the decision-making methodology used in this study. Our approach is innovative and robust in that the evaluation depends upon data collected from PV manufactures datasheets. Unlike traditional research, a hybrid AHP and QFD innovative decision making methodology has been created, and current commercial PV market data for all pairwise comparisons are used to show that methodology. Using both cooled and uncooled PV modules, best, intermediate, and worst-case scenarios were used to estimate the driving ranges of lightweight EVs powered exclusively by bulk silicon PV modules.

Diab-Marzouk et.al.,(2015) develop a silicon-carbide (SiC)-based dc–dc converter for the solarship, a manned solar aircraft for supply delivery in remote locations. The concept of differential power processing (DPP) is utilized to realize a high-efficiency lightweight converter that performs maximum power point tracking (MPPT) to transfer power from the aircraft’s wing-mounted solar array to the high-voltage lithium-battery bus. The isolated Cuk topology is augmented with an unfolder to achieve four quadrant operation and minimize the worst-case processed power. A small-signal model is derived for control design, and it is shown that the compensation strategy differs significantly based on the operating mode. The DPP Cuk converter is promising for emerging solar aerospace applications.

Galotto et. al., (2013) presents evaluations among the most usual maximum power point tracking (MPPT) techniques, doing meaningful comparisons with respect to the amount of energy extracted from the photovoltaic (PV) panel [tracking factor (TF)] in relation to the available power, PV voltage ripple, dynamic response, and use of sensors.

Esram et. al., (2007) provides a comprehensive review of the maximum power point tracking (MPPT) techniques applied to photovoltaic (PV) power system available until March, 2014. A good number of publications report on different MPPT techniques for a PV system together with implementation. But, confusion lies while selecting a MPPT as every technique has its own merits and demerits. Hence, a proper review of these techniques is essential.

III. STATE PLANE DIRECT MPPT CONTROL

The control scheme is developed in this section by combining the basis for MPPT set in this section with the large signal, state-plane model of the converter developed in this section.in this way, the proposed controller ensures large-signal reliable operation while ensuring maximum power extraction

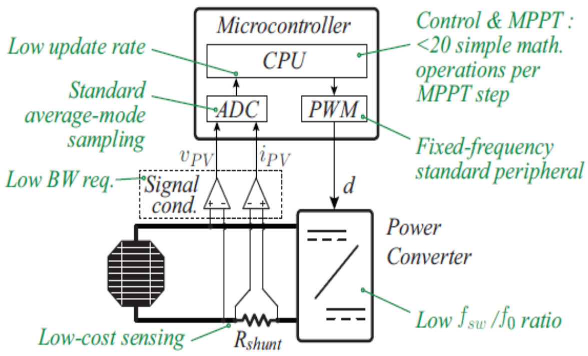


Fig. 2. Dynamic behavior of controller

As opposed to the traditional steady-state-based direct duty-cycle MPPT, the State-plane direct MPPT finds its cornerstone in the simple idea of continuously operating the power converter slightly away from its equilibrium conditions.

The dynamic behavior of the proposed controller is shown in Fig. 2 for an increasing PV voltage (v_{PVn}). As shown in the figure, the circle centre is periodically updated and set at a distance δ from the measured PV voltage (i.e.: $d_{[z+1]} = v_{PV\ n[z]} + \delta$). In this way, the equilibrium conditions are never met, and the operating point is continuously moving. The centre-updating mechanism is shown in Fig. 2: the PV voltage v_{PVn} is sampled at the instant indicated byΘ, and the centre (given by d) is then placed at a distance δ to the right, remaining at that location until a new update is performed. As shown in the figure, the inductor current (i_{Ln}, blue) describes fractions of spirals during the time the centre remains at a given location. The angle (α) covered by the operating point during an update period (t_U) is defined as a fraction of a turn given by the ratio between update and resonance periods:

$$\alpha = 2\pi \frac{t_U}{T_0} < \pi \tag{27}$$

The sign of the displacement is defined according to the desired PV voltage derivative defined. The embedded MPPT control rules can be found by plugging the above described control actions with the condition:

$$\begin{aligned} &\textit{if:}\ \left|\Delta i_{PV[z]}\right| v_{PV[z]} \le \left|\Delta v_{PV[z]}\right| i_{PV[z]} \\ &\textit{then:}\ d_{[z+1]} = v_{PVn[z]} + \delta \\ &\textit{else:}\ d_{[z+1]} = v_{PVn[z]} - \delta \end{aligned} \tag{28}$$

where $\Delta x_{[z]} = x_{[z]} - x_{[z-1]}$, $v_{PVn[z]}$ is the normalized PV voltage at the update moment (Θ), and δ << 1 is the displacement from the converter's equilibrium condition. In this way, the operating point is continuously moving in search of the maximum power point, and the proposed technique shows a dynamic solution for the dynamic problem of MPPT.

IV. SYSTEM IMPLEMENTATION

In this project, the proposed methodology is carried out and our objective is to present a MPPT algorithm is to maximize the charging current in every type of dynamic conditions. Around 95% voltage of the voltage rating is maintained by battery and slight voltage variation as well as current maximization is taken into the account by MPPT algorithm, so the combined results reach the MPP. It means, the overall responsibility of maximizing the charging current ot reaching the MPP, is on the shoulder of MPPT algorithm. Therefore, in this project, a new algorithm is proposed for MPPT.

In this project, we proposed a novel direct duty cycle control method that does not require the converter to achieve steady state in between MPPT updates. The proposed method benefits from the natural oscillations occurring in the converter to obtain extreme dynamic tracking improvements while maintaining simple implementation with no need of employing temperature or irradiance sensors. The scheme being introduced combines MPPT concepts with large-signal geometric control to achieve a reliable, high- performance solution.

This work proposes a novel theoretical framework based on state-plane modelling of the power converter. The analysis results in a new method of operating direct MPPT algorithms to enable extreme dynamic tracking improvements while maintaining simple implementation with no requirement of temperature or irradiance sensing.

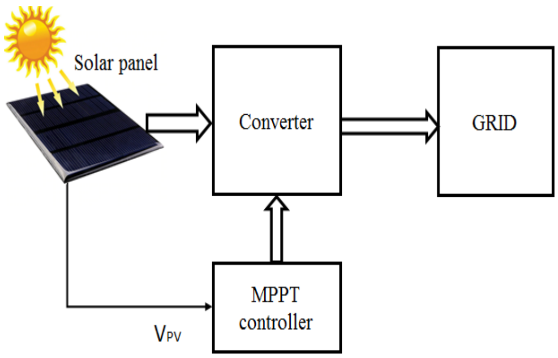


Fig. 3. Proposed block diagram

The proposed block diagram is shown in fig 3. In this block the PV panel is connected to grid through converter unit. The boost converter with PWM control from MPPT (Atmega328) controller using direct MPPT control.

The following figure represents the proposed hardware circuit diagram for this project.

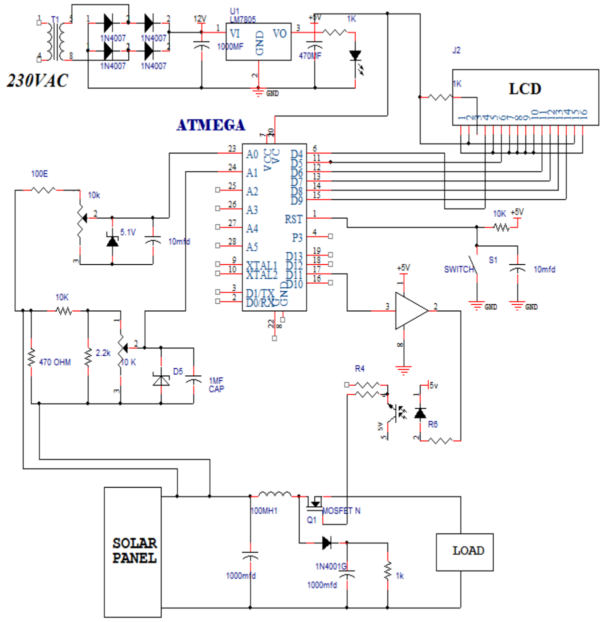


Fig. 4. Hardware implementation

In this figure 4, Power supply gives supply to all components. It is used to convert AC voltage into DC voltage. Transformer used to convert 230V into 12V AC.12V AC is given to diode. Diode range is 1N4007, which is used to convert AC voltage into DC voltage. AC capacitor used to charge AC components and discharge on ground. LM 7805 regulator is used to maintain voltage as constant. Then signal will be given to next capacitor, which is used to filter unwanted AC component. Load will be LED and resister. LED voltage is 1.75V.if voltage is above level beyond the limit, and then it will be dropped on resister. In our project, the solar panel is used for generating power using the PV cell present at the panel the solar energy is converted in DC sources signal. The generated power is given to the converter. The converter converts the DC – DC for more effective supply which is more applicable for running load. In this project used Atmega328 controller. The reset switch is connected to controller port 1 for resetting purpose. The solar panel voltage and current is monitor and measured through voltage and current measuring unit. It is given to controller port A0 & A1. Controller gives PWM signal to converter switch (IRF840) through opto coupler IC4n35. It is used to isolation between input and output. The DC to DC converter output is connected to load.

1. ATMEGA 328

ATmega328 is an 8-bit and 28 Pins AVR Microcontroller, manufactured by Microchip, follows RISC Architecure and has a flash type program memory of 32KB. It has an EEPROM memory of 1KB and its SRAM memory is of 2KB. It has 8 Pin for ADC operations, which all combines to form PortA (PA0 – PA7). It also has 3 builtin Timers, two of them are 8 Bit timers while the third one is 16-Bit Timer. You must have heard of Arduino UNO, UNO is based on atmega328 Microcontroller. It's UNO's heart. It operates ranging from 3.3V to 5.5V but normally we use 5V as a standard. Its excellent features include the cost efficiency, low power dissipation, programming lock for security purposes, and real timer counter with separate oscillator. It's normally used in Embedded Systems applications.

Atmega328 pin out:

Through pinout diagram we can understand the configurations of the pins of any electronic device, so you are working on any Engineering Project then you must first read the components' pinout.

- Functions associated with the pins must be known in order to use the device appropriately.
- ATmega-328 pins are divided into different ports which are given in detail below.
    - VCC is a digital voltage supply.
    - AVCC is a supply voltage pin for analog to digital converter.
    - GND denotes Ground and it has a 0V.
    - Port A consists of the pins from PA0 to PA7. These pins serve as analog input to analog to digital converters. If analog to digital converter is not used, port A acts as an eight (8) bit bidirectional input/output port.

- Port B consists of the pins from PB0 to PB7. This port is an 8 bit bidirectional port having an internal pull-up resistor.
- Port C consists of the pins from PC0 to PC7. The output buffers of port C has symmetrical drive characteristics with source capability as well high sink.
- Port D consists of the pins from PD0 to PD7. It is also an 8 bit input/output port having an internal pull-up resistor.

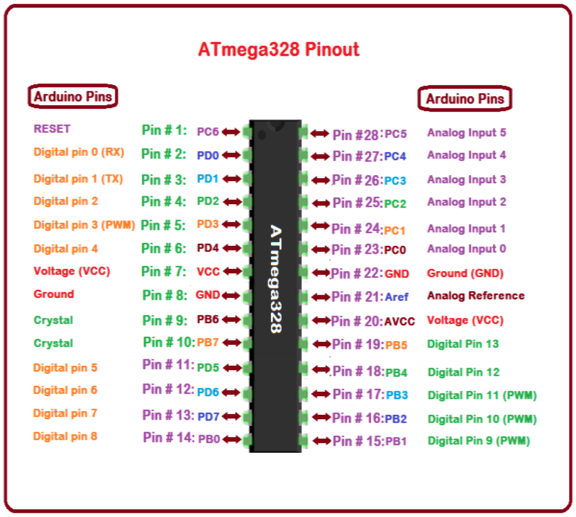


Fig. 5 Atmega328-Pinout

2. OPTO COUPLER

In electronics, an **opto-isolator**, also called an **optocoupler**, **photocoupler**, or **optical isolator**, is "an electronic device designed to transfer electrical signals by utilizing light waves to provide coupling with electrical isolation between its input and output". The main purpose of an opto-isolator is "to prevent high voltages or rapidly changing voltages on one side of the circuit from damaging components or distorting transmissions on the other side." Commercially available opto-isolators withstand input-to-output voltages up to 10 kV and voltage transients with speeds up to 10 kV/μs.

Pin Diagram – 4N35

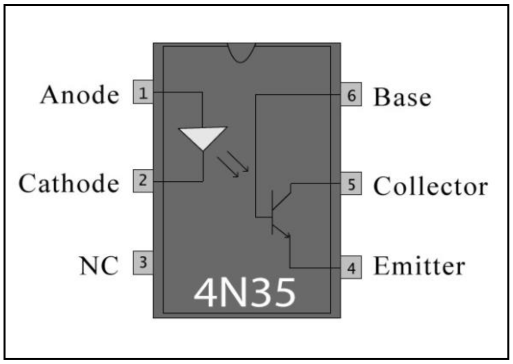


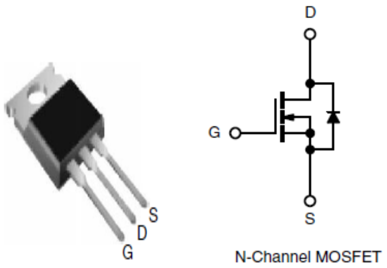
Fig. 6. Opto coupler-4N35

The LED is a light emitting device and photo transistor is a light sensitive device. The conduction current of phototransistor can be controlled via the conduction current of the LED, even though the two devices are physically separated. Such a package is known as an opto coupler, sine the input (LED) and the output (phototransistor) devices are optically coupled. The most important point to note about the opto coupler device is that a circuit connected to its input can be electrically fully isolated from the output circuit and that a potential difference of hundreds (or) thousands of volts can safely exist between these two circuits without adversely influencing the opto coupler action. This isolating characteristic is the main attraction of this type of opto coupler device, which is generally known as an isolating opto coupler.

3. IRF840

Third generation Power MOSFETs from Vishay provide the designer with the best combination of fast switching, ruggedized device design, low on-resistance and cost-effectiveness. The TO-220AB package is universally preferred for all commercial-industrial applications at power dissipation levels to approximately 50 W. The low thermal resistance and low package cost of the TO-220AB contribute to its wide acceptance throughout the industry.

Symbol



FEATURES

- Dynamic dV/dt Rating
- Repetitive Avalanche Rated
- Fast Switching
- Ease of Paralleling
- Simple Drive Requirements
- Compliant to RoHS Directive 2002/95/EC

V. RESULT AND DISCUSSION

The following figure shows the hardware presentation for direct MPPT project.

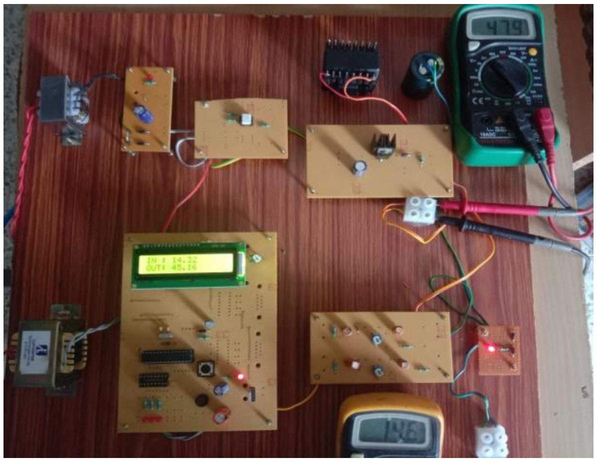
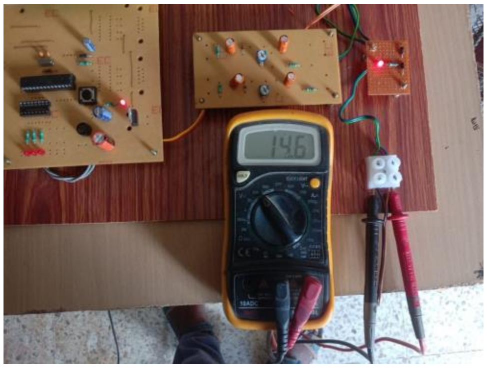
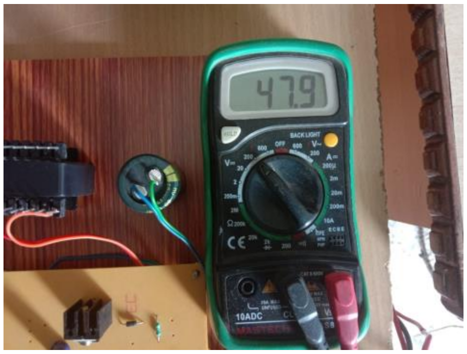


Fig. 7 Hardware kit

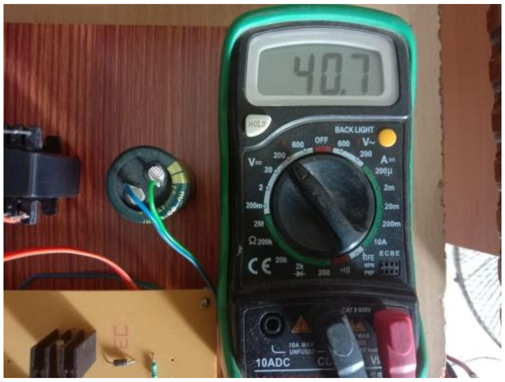
Fig. 8 Input and Output voltage

The following results shows the input and output voltage by using direct mppt method. The input voltage 14.9 and the output voltage 47.9





The input voltage 10.6 and the output voltage 40.7



The following table represents the comparison for input and output voltage to the existing, proposed MPPT control.

Input voltage	**Perturbation and Observation (P&O) (Existing)**	**Direct MPPT (Proposed)**
10.6	29.7	40.7
14.32	33.4	45.16
14.9	36.8	47.9

VI. CONCLUSION

This work introduced a novel approach for performing direct duty-cycle MPPT in photovoltaic energy harvesting applications: the State-plane direct MPPT. By employing stateplane analysis, the large-signal dynamic behaviour of the PVconnected power converter was modelled in a straightforward geometric manner. Using this geometric model, an increase in the direct MPPT algorithm updating frequency of two orders of magnitude was enabled (e.g. from 20 T0 to T0 8 in the analysed example). The much higher updating frequency resulted in extreme enhancements in the MPPT dynamic tracking performance compared to traditional solutions. Detailed mathematical procedures were provided to support the proposed methodology. The extreme improvements were confirmed through simulation results and under the dynamic test standard EN50530 including a speed multiplier to reach the typical irradiance change rates found in moving PV applications (i.e. backpack, bike, car). A step-by-step design procedure, an example application, and a detailed hardware implementation diagram were provided, highlighting the relevance of the contribution of the work to the applied field. The theoretical framework and design procedure were validated by simulation and experimental results in 65W and 50W platforms, respectively.

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