Abstract—This paper introduces a cascaded dc-dc converter which combines both Ćuk and buck converter topologies to extract maximum power from photovoltaic arrays while supplying a controlled constant current/voltage to the battery simultaneously. The converter uses two control signals; one for maximum power point tracking, another for battery charger control providing constant current/voltage to the battery. The advantage of this converter is extracting the maximum power of the PV array avoiding battery damage caused by variable MPPT voltage. Batteries need constant voltage and current for charging to avoid the damage and to extend its lifetime. Therefore, it is reliable to combine the battery charger control and the maximum power exploitation using two control signals simultaneously.

Keywords: battery charger; DC/DC converter; maximum power point tracker

I. INTRODUCTION

Standalone systems dispense with the grid, so they need batteries to store the energy supplying the load when the solar-energy production is low. Storage batteries need a deep cycle to discharge a significant amount of the stored energy. The commonest deep-cycle battery is nickel-cadmium through it costs more than does lead-acid battery. Valve-regulated lead-acid (VRLA) battery has been widely used in PV applications recently. It is low-cost, maintenance-free, and considered the most recyclable among batteries [1]. For long battery life, a charge controller preventing complete discharging and surplus charging is needed. Battery life reduces when the PV-produced energy is low. Therefore, the converter needs maximum power point tracker (MPPT) control.

The cascaded converter, Ćuk-buck, uses two switches. The first switch is responsible for extracting the maximum power, and the second one is responsible for the control of the battery charger. The buck part can convert voltage from PV variable voltage to 58V, charging the battery with high current. Ćuk-buck converter can extract maximum power as well as control battery charger simultaneously without losing the control of any part.

Unlike research in MPPT and battery charger, combined research in MPPT for battery charger is rarely reported. In MPPT for battery charger, one control signal controls only one system (either charger or MPPT) at any single time. When the converter uses one control signal, the voltage supplying the battery is either not constant (the absence of voltage control possibly damaging battery), or constant (hence MPP cannot be achieved).

One of the most important issues that must be taken into consideration of the PV converter applications is the flowing of input current. Some converters like buck or buck-boost converter have a switch in series with the PV source. This series switch can lose half of the power available from the PV array. The other important thing is the independency of control functions. Therefore, the use of two control switches for each function will definitely improve the desired output for each function. Buck converter as a battery charger for standalone system is proposed in [2] and [3]. One control switch is used for SEPIC converter to control both MPPT and the battery charger [4]-[6]. In [7], the author used buck-boost converter to charge the battery with MPPT.

This paper describes a charger achieving maximum exploitation of power, and longer battery lifetime. The next sections of this paper are organized as follows: Section II describes the analysis of the converter, Section III presents the simulation results, and Section IV draws the conclusions.

II. ANALYSIS OF ĆUK-BUCK CONVERTER

The Ćuk-buck operation starts when the first switch $S_1$ turns on at time $t=0$, at which the moment current in inductor $L_1$ increases and the voltage on the capacitor turns off diode $D_1$. The first capacitor $C_2$ discharges its energy to the circuit when $S_1$ turns of at time $t=t_1$. The second switch $S_2$ instantaneously turns on depending on the feedback signal from the battery at time $t=t_2$. The current of $S_2$ passes through $L_3$, $C_b$, and the load. Once $S_2$ turns off at time $t=t_2$, the diode $D_2$ is connected owing to the energy stored in $L_3$. Fig. 1 shows the diodes and the switches, $D_1$, $D_2$, $S_1$, and $S_2$ providing synchronous switching action.

Now, a very small scope of the current through $L_1$ is taken as shown in Fig. 2, where the current $I_1$ can be shown linearly during time $t_{on}$. According to Fig. 2, equation (1) can be concluded.

![Fig. 1. Ćuk-buck circuit showing the synchronization of switches and diodes.](image-url)