DESIGN AND SIMULATION OF HYBRID SYSTEM FED MULTIPLE INPUT SINGLE OUTPUT CUK DC-DC CONVERTER

Anto jude rajeshkumar M. and Sripriya, R.

ME. Power electronics and drives, EEE Department, Jerusalem college of engineering, Chennai 600100. antojudem.vec@gmail.com

ABSTRACT

This thesis entails the design of a multiple-input CUK dc-dc converter. The converter will be used to interface multiple power sources such as those obtained from renewable energy sources. This paper presents a new system configuration which allows the two sources to supply the load separately or simultaneously depending on the availability of the energy sources. The inherent nature of this Cuk converter is that the additional input filters are not necessary to filter out high frequency harmonics. Harmonic content is detrimental for the generator lifespan, heating issues, and efficiency. Results from the theoretical calculation and simulation are presented in the report which demonstrates the functionality and performance of the proposed converter.

Keywords — Cuk converter, Multiple input single output, step input, PI controller, closed loop system.

I. INTRODUCTION

1.1 DC-DC CONVERTERS

This DC to DC converter is important in portable electronic devices which are supplied with power from batteries primarily. Such electronic devices often contain several sub-circuits, each with its own voltage level requirement different from that supplied by the battery or an external supply. Switched DC to DC converters offer a method to increase voltage from a partially lowered battery voltage thereby saving space instead of using multiple batteries to accomplish the same thing. Some exceptions include high-efficiency power sources, which are a kind of DC to DC converter that regulates the current through simple charge pumps which double or triple the output voltage. In DC-to-DC converters, energy is periodically stored into and released from a magnetic field in an inductor typically in the range of 300 kHz to 10 MHz by adjusting the duty cycle of the charging voltage, the power transferred can be controlled. Usually, converters are used to control the output voltage, though it could be applied to control the input current, the output current, or maintain a constant power. Transformer-based converters may provide isolation between the input and the output. In general, the term "DC-to-DC converter" refers to one of these switching converters.

II. CUK DC-DC CONVERTERS

A Many years ago, Dr. Cuk invented the integrated magnetic concept called DC transformer, where the sum of DC fluxes created by currents in the winding of the input inductor L1 and transformer T is equal to DC flux created by the current in the output inductor L2 winding. Hence the DC fluxes are opposing each other and thus result in a mutual cancellation of the DC fluxes. Cuk converter has several advantages over the buck converter. One of them cuk converter provide capacitive isolation which protects against switch failure. The circuit arrangement of the Cuk converter using MOSFET switch is shown in Figure 2.1. When the input voltage is on and MOSFET (S1) is switched off, diode D1 is forward biased and capacitor Cc is charged through L1-D.

Here the operation of converter is divided into two modes.

2.2.1 Page Modes Of Operation - Cuk Converter

Mode-1:- When MOSFET switch is turned on at t=0, the current through L1 rises. At the same time, the voltage of Cc reverse biases diode D and turns it off. The capacitor Cc discharges its energy to circuit Cc-Co-load L2.

2.2.2 Cuk converter with switch ON
Mode-2: When MOSFET switch is turned off at $t = t_1$. The capacitor will start to charge from input supply $V_{in}$ and the energy stored in the inductor transferred to the load is shown in Figure 2.3. The capacitor $C_c$ is the medium for transferring energy from source to load. The values assigned for the circuits designed are obtained from the design calculations. It is a calculation to find out the value of each element to obtain the expected output. The design calculation for the cuk converter for the boost operation is given below.

![Cuk Converter with Switch OFF](image)

**Figure 2.3. Cuk Converter with Switch OFF**

### 2.2.2 Design Calculation of Cuk Converter-Boost Operation

**Finding the values of $L$ and $C$: FORMULA:**
- Duty cycle ($D$): $D/(1-D) = V_o/V_{in}$
- Inductor $L = (V_{c1} - V_d) (1-D) T_s / \Delta i_{L1}$
- Coupled capacitor $C_c = D/2fR$
- Output capacitor $C_o = 1/8fR$

**CALculated VALUES:**
- Input voltage $V_{in1} = 24v$
- Output voltage $V_o = 48v$
- Duty cycle $D = 0.67$
- Inductors $L_1, L_2 = 6.336mH$
- Coupled capacitor $C_1 = 13.4uF$
- Output capacitor $C = 500uF$

### 2.2 Circuit Diagram of Multiple Input CUK DC-DC Converter

The Figure 2.4 shows the circuit diagram of multiple input CUK dc-dc converter. It consists of a cuk fused multi-input dc–dc converter. The input dc voltage sources, $V_{PV}(V_{in1})$ and $V_{wind}(V_{in2})$, are obtained from the PV array and the rectified wind turbine output voltage.

![Circuit diagram of multiple input CUK dc-dc converter](image)

**Figure 2.4. Circuit diagram of multiple input CUK dc-dc converter**

### Design Calculations of Multi-Input CUK DC-DC Converter-Boost Operation, Finding the values of $L$ and $C$: FORMULA:

- Duty cycle ($D$): $D/(1-D) = V_o/V_{in}$
- Inductor $L = (V_{c1} - V_d) (1-D) T_s / \Delta i_{L1}$
- Coupled capacitor $C_1, C_2 = D/2fR$
- Output capacitor $C_o = 1/8fR$

**CALculated VALUES:**
- Input voltage $V_{in1} = 24v$
- Input voltage $V_{in2} = 12v$
- Output voltage $V_o = 48v$
- Duty cycle $D = 0.67$
- Inductors $L_1, L_2 = 6.336mH$
- Coupled capacitor 1 $C_1 = 13.4uF$
- Coupled capacitor 2 $C_2 = 13.4uF$
- Output Capacitor $C = 500uF$

### III. PAGE SIMULATION RESULTS OF CUK DC-DC CONVERTERS

#### 3.1 MATLAB

The name MATLAB stands for matrix laboratory. MATLAB is a high performance language for technical computing. It integrates computation, visualization and programming in an easy to use environment and problems and solutions are expressed in familiar mathematical notation.

#### 3.2 SIMULINK MODEL OF CUK DC-DC CONVERTER

Figure 3.1 illustrates the simulation of a CUK converter. The output voltage $V_0$ is greater than the input voltage $V_s$. The CUK converter operates in two modes of operation.

![Simulink Model of CUK Converter](image)

**Figure 3.1 Simulink Model of CUK Converter**

The CUK converter simulation has the following output current and voltage waveforms.

**Output Waveforms:**

![Output current and voltage waveforms of CUK converter](image)

**Figure 3.2 Output current and voltage waveforms of CUK converter**
The output current is observed as 0.5A and the required output voltage is 48V where the observed value is 48V. The output waveforms of current and voltage is shown Figure.3.2. The current waveforms has the plots between current and time. The voltage waveforms has the plots between voltage and time.

3.3 SIMULINK MODEL OF MULTIPLE INPUT CUK DC-DC CONVERTER

The Figure.3.3 represents the Simulink model of multiple input CUK dc-dc converter. The circuit consists of CUK converter connected in such a way that input side has multiple inputs. Here, V1 has to be greater than that of V2 such that all the three mode of operations could be studied. The MJ CUK dc-dc converter has the circuit that consists of a resistive load of 100 ohms. It operates with input voltages V1=24V & V2=12V. By varying the duty cycle of the converters output can be varied. The converter switching frequency F which is fed into each of the switches in corresponding inputs is kept constant.

Figure.3.3. Simulink model of MI CUK DC-DC converter system

The duty cycle also varies from one input to the other in the converter. The switching frequency for both the converter switches is 20000 Hz. The duty ratio for first mode operation is 25% and for second mode is 75%. Output Waveforms: The output current is observed as 0.5A and the observed value is 48V. The output waveforms of current and voltage is shown Figure.3.4.

4.3.1 Output Waveforms

The output current is observed as 0.8A and the required output voltage is 48V where the observed output voltage is 48V.
Figure 4.6 Current and voltage output waveforms of PV-WECS fed multi-input CUK dc-dc converter

V. SIMULATION RESULTS OF CUK DC-DC CONVERTER WITH CLOSED LOOP CONTROL

5.1 GENERAL
This chapter deals about Simulink model of closed loop control of multi-input CUK dc-dc converter with step change in load.

5.2 SIMULINK MODEL OF MI CUK DC-DC CONVERTER SYSTEM WITH STEP CHANGE IN LOAD
The multiple input CUK dc-dc converter with a closed loop module at the load side is shown in Figure 5.1. It has a reference that has been set at 48V. Here along with the closed loop module, a step input is inducted into the system. The step change is set at 0.5 time units.

5.2.1 Output Waveforms
The output voltage and current waveforms are shown in the Figure 5.2. The output voltage is 48V and current is 0.5A with the step change of the load at 0.5 time units. Considering the voltage characteristics in the period before the step change is induced, the initial peak overshoot is not as high and settles for a voltage at 48V. Here it is to be noted that the reference value set is 48V. With the given step change in the load, the output voltage oscillates and the closed loop control tries to bring it to the reference value of 48V.

Figure 5.1 Simulink model of multi-input CUK dc-dc converter with step change in load

A. SIMULINK MODEL OF CUK DC-DC CONVERTER WITH CLOSED LOOP CONTROL
The Simulink model of the buck fed buck converter operated with PI controller is shown in Figure 5.3. Once the load is switched on current starts to build up and voltage reaches the set value. This is done using the PI controller, which is as follows. We go for voltage closed loop control, so the reference voltage is been set as 48V. The output is compared with the input using the reference value. The error from comparator is given to the PI controller. PI controller gives the control output, but we require pulses to drive the MOSFET placed in converter circuit. So the controller output is compared with carrier signal to generate pulses. The switching frequency of the converter is based on carrier frequency which is 5 KHz. To reach the set value PI controller has to be tuned. We go for error and trial tuning method. After
several steps, the tuned PI values of Kp is 0.07 and Ki is 0.04.

Considering the voltage characteristics in the period before the step change is induced, the initial peak overshoot is not as high and settles for a voltage at about 48V. Here it is to be noted that the reference value set is 48V. The output voltage oscillates and the closed loop module tries to bring it to the reference value of 48V. The step change is not

VI. CONCLUSION
This work deals with the circuitry and principle of operation of multiple input CUK dc-dc converter and its modes of operation. The performance of the proposed multi-input power converter system is studied with various inputs and is verified with the simulation results. Steady state error is high in open loop system. Steady state error is reduced using closed loop system. A combination of solar and wind energy sources improves overall energy output especially if they are connected to grid. MPPT feature for both PV and wind energy has to be realized.

REFERENCES