Design of Control Power Supply Using Ultra-capacitor

Dhaval Patel ¹, Sanjay K. Patel ²

¹PG STUDENT Final Year, Dept. Of Electrical Engineering, Nirma University, Ahmadabad, India
²Assistant Professor, Dept. Of Electrical Engineering, Nirma University, Ahmadabad, India

Abstract: High power converters are used in drive applications. The control power supply needs to ensure that any glitch in the grid side does not affect any of control circuit boards. The project gives the ride through system developed to overcome voltage sags and short duration outages at the power supply terminals of the control cards in these converters. A 13.5v buck-boost converter has been designed to be used along with a stack of ultra capacitors to achieve the same. A micro-controller based digital control platform is made use of to achieve the control objective. The design of the ultra capacitors stack and the Buck-boost converter is described and the performance of the simulation is evaluated.

Keywords: Ultra capacitor, Super capacitor, Power Supply, buck-boost converter.

I. INTRODUCTION

Power electronics systems or power processors almost in every topology, with the exception of very special cases such as matrix converters, have the need of energy storage devices to provide energy backup and decoupling between different power conversion stages. Traditionally due to their low cost the most commonly used storage devices are electrolytic capacitors and batteries, but they have some drawbacks such as size, performance and life. There are several new energy storage technologies available today. Among these new energy storage devices ultra capacitor appear to be a good option for applications that require high power densities and fast transient response, and all this in a reduced volume. Ultra capacitor are polarized devices, as are conventional electrolytic capacitors, but they differ in that ultra capacitor have capacitance values ranging from 1 F to 2700 F and their equivalent series resistance is typically 10 times lower than conventional capacitors. An application of ultra capacitor in power electronics systems is as backup energy storage for systems subjected to a reduction to their input voltage.

II. BUCK-BOOST CONVERTER

The dc-dc converters can have two distinct modes of operation: Continuous conduction mode (CCM) and discontinuous conduction mode (DCM). In practice, a converter may operate in both modes, which have significantly different characteristics. Therefore, a converter and its control should be designed based on both modes of operation. However, for this course we only consider the dc-dc converters operated in CCM. When the switch is on for a time duration DT, the switch conducts the inductor current and the diode becomes reverse biased. This results in a positive voltage. 

$$V_L = Vin$$

When the switch is turned on, because of the inductive energy storage, $I_L$ continues to flow. This current now flows through the diode, and 

$$V_L = -V_O$$

for a time duration (1-D)T until the switch is turned on again.

![Buck-boost converter topology](image)
III. MODELLING OF ULTRA CAPACITOR

For better describing the total behaviour of the ultra capacitor, the model of two branches has been completed by the equivalent circuit of self discharge. Fig 2 represents the model. The fast branch R1C1 represents the main behaviour during charge and discharge of the ultra capacitor. The new branch C2, Rf2 represents the second exponential behaviour during the self-discharge. The capacity C1 varies linearly with the voltage at its terminal. The slow branch R3, C3 describes the redistribution of the charges inside the ultra capacitor.

![Model of ultra capacitor](image1)

Figure. 2 Model of ultra capacitor

A. Determination of $R1$ and $C$

The entire Fig 3 represents the ultra capacitor voltage variations as a function of time. The charge and discharge are realized at constant current $I$. The resistant $R1$ is deduced from the voltage increment $\Delta u'$ with the following equation:

$$R_1 = \frac{\Delta u'}{I}$$

![Ultra capacitor voltage variations as a function of time](image2)

Figure. 3 Ultra capacitor voltage variations as a function of time.
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During the charge and discharge, the total impedance of the resistive branch (Rf1; Rf2) is much greater than the total impedance of the capacitive branch (C1; C2). The influence of Rf1 and Rf2 during the charge and the discharge is thus negligible. For the charge and the discharge the proposed model is thus simplified by the model (Model of two branches) by considering:

\[ C = C_u + \Delta C = \frac{C_1 \times C_2}{C_1 + C_2} \]
\[ C_0 = \frac{I}{\Delta u(0)} \]
\[ R' = 2 \times \left( \frac{I \times \Delta C_0 \times \Delta u}{\Delta u^2} \right) \]

Where, \( T_c \) is the total charging time. The voltage increment \( \Delta u \) is indicated in figure.

**B. Determination of C1 and C2**

Figure 3 represents the voltage at the terminals during a self-discharge after a charge with a constant current I. As soon as the value of \( C = C_1 \times C_2 / (C_1 + C_2) \) is determined, C1, C2, Rf1 and Rf2 can be deduced by a test of self-discharge. Considering that C1 and C2 are charged in series, \( Q_1 = Q_2 = Q = I \times \Delta t \) can be written, where Q is the charge stored in C1 and Q2 is the charge stored in C2. Thus, from the basic definition of the capacity \( C_1 \Delta u_1 = C_2 \Delta u_2 \) can be written. The relationship between the two capacities with the initial voltages at the beginning of the self-discharge of each capacity is: \( C_1/C_2 = u_1/u_2 \)

**C. Determination of RF1 and RF2**

The study of the evolution of the curve of self discharge shows that it includes two exponential decreasing superimposed. Their respective time constants \( t_1 \) and \( t_2 \) can be defined:

\[ t_1 = R_f \times C_1 \]
\[ t_2 = R_f \times C_2 \]

![Figure 4](image-url)

Figure 4 Separation of the curve of self-discharges into 2 exponentials.
D. Determination of C3 and R3

As soon as the charging current disappeared, take place the internal redistribution of the charges stored between the branch CR1 and C3R3 (the slow branch in the model of two branches). Note well that here the slow branch is supposed not charged during that allows a Thus, the equivalent capacity C discharges to the slow branch constituted by R3 C3. The average redistribution current \( I_r \) (discharge current for C) is given by:

\[
I_r = \frac{U_{\text{begin}} - U_{\text{end}}}{\Delta t}
\]

\[
\Delta t = T_{\text{begin}} - T_{\text{end}}
\]

From this approximation:

R3 can be deduced.

The value of the capacity C3 can be calculated at the end of this period when the voltages across C and C3 are supposed equal to the same value. By using the equation of the charge conservation, the value of C3 is deduced by:

\[
C \Delta U_{\text{begin}} = C_3 \Delta U_{\text{end}} + C \Delta U_{\text{end}}
\]

IV. SIMULATION RESULTS

The model parameters method calculation described above is applied to determine the equivalent circuit model of two super capacitors. The super capacitor value is 450F and 2.7V have presented here as an example.

The model parameters are:

\[
\begin{align*}
R_1 &= 2.5 \text{m}\Omega \\
C_1 &= 360 + 110 u_1 \text{ (F)} \\
C_2 &= 3250 \text{ F} \\
R_{11} &= 3000 \text{\Omega} \\
R_{12} &= 1.33 \text{\Omega} \\
C_3 &= 33 \text{ F} \\
R_3 &= 0.8 \text{\Omega}
\end{align*}
\]
A. Simulation of Buck-Boost Converter for Ultra capacitor Interfacing:

As shown in the model a buck-boost converter is connected with ultra capacitor, which is working as supply to the converter. This ultra capacitor is pre charged at voltage 13.5v. In buck-boost converter mosfet works as a switch gated with pwm scheme. At a time switch is ON, inductor stores energy. Diode isolates input from the output. Capacitor supplies the resistive load connected in parallel. When the switch is OFF, the inductor stored energy charges the capacitor and supplies the load through the diode. This circuit provides constant 12v as output. Till the voltage across capacitor is more than 12v, it works as buck converter and as soon as it reaches less than 12v it starts working as boost converter. In both the condition the output voltage remains constant 12v. This output voltage is taken as feedback and given to pi controller. The output of this controller works as the comparator for triangular repeating sequence. The simulation of Buck-Boost converter is being carried out. The simulation model consists of a DC voltage followed by a Buck-Boost converter followed inductor L = 5 mH two inductor in series and capacitor C =100µF.

Figure 6: Input Voltage and Output voltage wave forms.

**Figure 6** Input Voltage and Output voltage wave forms.

**Figure 7** Input Current and Output Current wave forms.
In this paper ultracapacitor is modeled using two r-c branches which works as input to the system and provides 13.5V. Then it was synchronized with buck-boost converter. And from the simulation we observed that the circuit provides continuous 12V at output terminal.

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**REFERENCES**

[5] Sanjaya Maniktala. "Switching power supplies a to z". Copyright 2006, Elsevier Inc. All rights reserved, pp. 47 - 72.

**BIOGRAPHY**

**Dhaval Patel** receives his B.E in Electrical Engineering from Valia Institute of Technology, Valia, veer narmad south gujarat university (VNSGU) and currently pursuing M.E (Final Year) power Electronics Machines and Drives at Institute of Technology, Nirma University. His research interests include Power electronics converter, ups system.
Sanjay Patel has completed his M. Tech in electrical engineering from Indian Institute of Science (IISc), Bangalore in 2010. He is working as Assistant Professor in the Electrical Engineering Department at Nirma University, Ahmedabad. He is mainly interested in the area of power electronics include power electronics converter, Power Electronics applications to DG Systems and motor drives.