

DC/DC CONVERTER DESIGN FOR SUPER CAPACITOR AND BATTERY POWER MANAGEMENT IN RENEWABLE ENERGY SOURCE APPLICATION

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Abstract-This paper presents super capacitor (SCAP) and battery modeling with an original energy management strategy in a hybrid storage technology. The studied dc power supply is composed of SCAPs and batteries. SCAPs are dimensioned for peak power requirement, and batteries provide the power in steady state. A bidirectional dc/dc converter is used between SCAPs and the dc bus. Batteries are directly connected to the dc bus. The originality of this study is focused on SCAP behavior modeling and energy management strategy.

I. INTRODUCTION

Many research works are undertaken on technologies of future DC motor. Battery power request in transient state decreases its life span. To solve this problem of battery and supercapacitor (SCAP) hybridization, there must be good energy management between these devices which enables the reduction of the battery size and improves its life span. The battery and SCAP energy coupling improves the autonomy and performance of the motor. For autonomy problems, the traction battery used until now cannot satisfy the energy needs of future vehicles.

A renewable energy source is a vehicle that combines, in addition to its main energy source (oil and gas), reverse energy storage devices like flywheels, SCAPs, and batteries. These technologies which associate SCAPs and batteries are very promising in short and medium terms due to the SCAPs' high dynamic performances and their life span of about ten years longer than that of a battery. The SCAPs have power density from 10 to 100 times larger than that of a battery with an energy density that is much smaller. Moreover, these high-power storage devices present less risk of pollution than batteries. The main contribution of this paper presents two aspects.

The first is based on SCAP behavior modeling with an original method for experimental

parameter identification. The second aspect is focused on a novel strategy of embedded energy management using micro controllers. To validate the proposed method, a SCAP module and two dc/dc converter topologies are designed at reduced scale. This solution is due to the reason of cost and existing components, such as the batteries and the semiconductors. These converters are controlled by a PIC89V51RD2BN microcontroller. The experimental data acquisition system is monitored by using the National Instruments Lab view software. For hybrid system simulations, the SABER software package is used.

II. SOLAR PANEL

Photovoltaic (PV) power systems convert sunlight directly into electricity. A residential PV power system enables a home owner to generate some or all of their daily electrical energy demand on their own roof, exchanging daytime excess power for future energy needs (i.e. nighttime usage). The house remains connected to the electric utility at all times, so any power needed above what the solar system can produce is simply drawn from the utility. PV systems can also include battery backup or uninterruptible power supply (UPS) capability to operate selected circuits in the residence for hours or days during a utility outage.

The purpose of this document is to provide tools and guidelines for the installer to help ensure that residential photovoltaic power systems are properly specified and installed, resulting in a system that operates to its design potential. This document sets out key criteria that describe a quality system and key design and installation considerations that should be met to achieve this goal. This document deals with systems located on residences that are connected to utility power, and does not address the special issues of homes that are remote from utility power.

In this early stage of marketing solar electric power systems to the residential market, it is advisable for an installer to work with well established firms that have complete, pre-engineered packaged solutions that accommodate variations in models, rather than custom designing custom systems. Once a system design has been chosen, attention to installation detail is critically important. Recent studies have found that 10-20% of new PV installations have serious installation problems that will result in significantly decreased performance. In many of these cases, the performance shortfalls could have been eliminated with proper attention to the details of the installation.

III. DC-DC CONVERTER

The main goal of this chapter is to establish the DC/DC converter control for energy management between the SCAPs and the battery. This study is based on the buck-boost converters with battery and super capacitor for energy management technology. The SCAP modules are connected to the DC bus and full bridge converter controlled DC motor via buck-boost converters, which ensure the SCAP charge and discharge. The used converter topologies are shown in Figs (3.1).

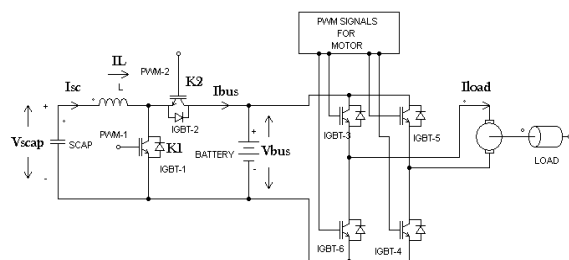


Fig.-1 Schematic of Buck-Boost Converter

IV. CONVERTER MODELING

To model these converters, the buck and boost converter operating modes must be analyzed. The buck converter mode energy is transferred from DC bus to super capacitor and boost converter mode energy is transferred from super capacitor to DC bus.

i) BUCK CONVERTER MODE

During buck converter mode, The DC bus having surplus power and the bus voltage is greater than

the voltage across SCAP. During this mode K2 semiconductor is ON, while K1 is OFF, The surplus power is transferred from DC bus to SCAP through K2. The Current flowing through super capacitor (I_{sc}), Inductor current (I_L) and DC bus current (I_{bus}) are supposed negative during the SCAP energy storage

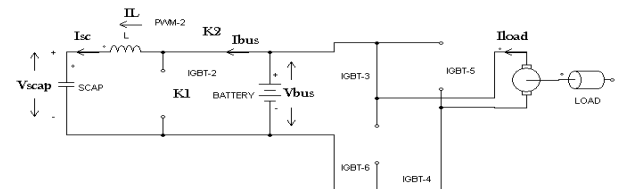


Fig.-2 Buck Converter mode Circuit

ii) BOOST CONVERTER MODE

During boost converter mode, The DC bus voltage is dropped due to load fluctuation and the bus voltage is less than the voltage across Supercapacitor. During this mode K1 semiconductor is forward biased and it is controlled by PWM pulses from microcontroller, while K2 is OFF. During this mode, the stored power in super capacitor is transferred to DC bus via K2 semiconductor body diode. Here inductor is used to boost the voltage across K1 for high power application. The Current flowing through super capacitor (I_{sc}), Inductor current (I_L) and DC bus current (I_{bus}) are supposed to positive during the SCAP energy discharge.

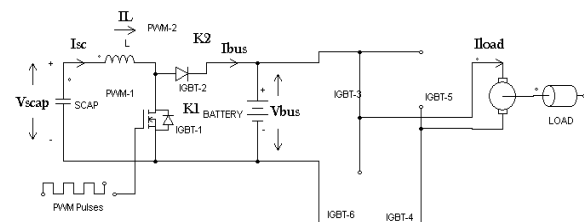


Fig.-3 Buck Converter mode Circuit

During K1 semiconductor is ON, The voltage across IGBT-1 is zero. The SCAP current is flowing through the inductor and generate voltage across the inductor. When the K1 semiconductor is OFF, the voltage across the IGBT-1 is equal to sum of voltage across the

SCAP and inductor. The voltage across the IGBT-1 which makes the IGBT-2 body diode into forward bias and energy transferred from SCAP to DC bus. The equivalent circuit for boost mode and energy transfer mode is shown in Fig.-4 and Fig.-3.

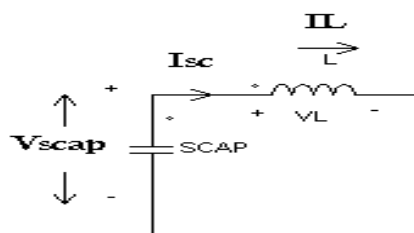


Fig.-4 Equivalent circuit of Boosting Mode

$$\text{Voltage across the inductor } V_L = L \frac{dI_{sc}(t)}{dt} \text{ Volts}$$

Where

L = Inductance of the coil

I_{sc} = Current flowing through SCAP.

$I_{sc}(t)$ = Current flowing through SCAP

$$\frac{V_{scap}}{R_t} e^{-(R_t/L)t} \text{ Amps (3.2)}$$

Where

1. R_t = Total resistance of the circuit.
2. Total resistance of the circuit $R_t = R_{scap} + R_{ind}$
3. R_{scap} = Resistance of super capacitor
4. R_{ind} = Resistance of inductor

$$\text{Energy stored in inductor } W_L(t) = \frac{1}{2} L (I_{sc}(t))^2 \text{ Joules}$$

$$\text{Energy stored in capacitor } W_c(t) = \frac{1}{2} C (V_{scp}(t))^2 \text{ Joules.}$$

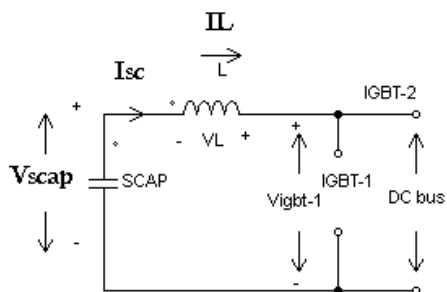


Fig.-5 Equivalent circuit of Energy Transfer Mode

$$\text{Voltage across IGBT-1 } V_{IGBT-1} = V_{scap} + V_L$$

V. SUPERCAPACITORS

Supercapacitors, also called ultra-capacitors and electric double layer capacitors (EDLC) are capacitors with capacitance values greater than any other capacitor type available today. Capacitance values reaching up to 400 Farads in a single standard case size are available. Supercapacitors have the highest capacitive density available today with densities so high that these capacitors can be used to applications normally reserved for batteries.

Supercapacitors are not as volumetrically efficient and are more expensive than batteries but they do have other advantages over batteries making the preferred choice in applications requiring a large amount of energy storage to be stored and delivered in bursts repeatedly.

- Power density
- Recycle ability
- Environmentally friendly
- Safe
- Light weight

Activated carbon Electrode

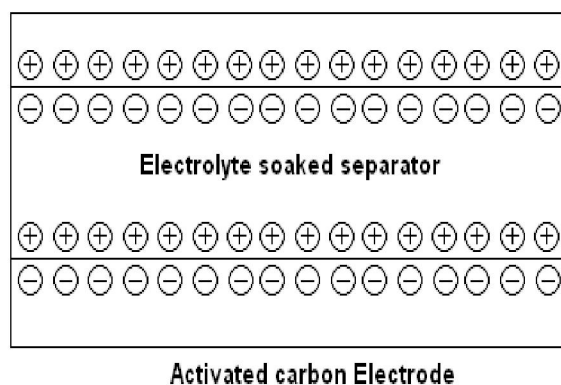


Fig.-6 Structure of super capacitor

The most significant advantage supercapacitors have over batteries is their ability to be charged and discharged continuously without degrading like batteries do. This is why batteries and supercapacitors are used in conjunction with each other. The supercapacitors will supply power to the system when there are surges or energy bursts since supercapacitors can be charged and discharged quickly while the batteries can supply the bulk energy since they can store and deliver larger amount energy over a longer slower period of time.

VI. HOW TO MEASURE THE CAPACITANCE OF A SUPER CAPACITOR

There are a couple of ways used to measure the capacitance of super capacitor.

1. Charge method
2. Charging and discharging method.

CHARGE METHOD

Measurement is performed using a charge method using the following formula.

$$C=t/R$$

t = Time taken for this voltage to reach .632 V_0

Where T is the time constant

CHARGE AND DISCHARGE METHOD

This method is similar to the charging method except the capacitance is calculated during the discharge cycle instead of the charging cycle.

Discharge time for constant current discharge

$$t = C_x (V_0 - V_1) / I$$

Discharge time for constant resistance discharge

$$t = CR \ln (V_1 / V_0)$$

Where t = discharge time, V_0 = initial voltage, V_1 = ending voltage, I = current.

LIFE EXPECTANCY

The life expectancy of supercapacitors is identical to aluminum electrolytic capacitors. The life of super capacitors will double for every 10°C decrease in the ambient temperature the capacitors are operated in.

Super capacitors operated at room temperature can have life expectancies of several years

Compared to operating the capacitors at their maximum rated temperature.

$$L_2 = L_1 * 2^X \quad X = T_m - T_a$$

L_1 = Load life rating of the super capacitor.

L_2 = expected life at operating condition.

T_m = Maximum temperature rating of the supercapacitor.

T_a = Ambient temperature the supercapacitor is going to be exposed to in the application.

VII. SIMULATION

SIMULATION DIAGRAM AND RESULTS

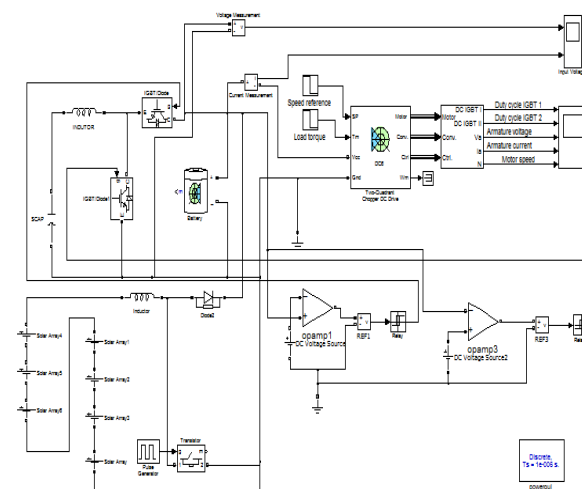
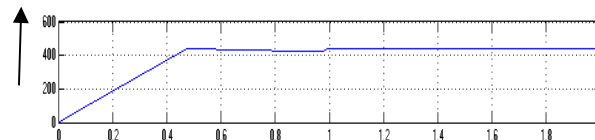


Fig.-7 Simulation Diagram

BATTERY VOLTAGE Vs TIME IN SECOND

BATTERY
VOLTAGE



TIME IN SECOND

BATTERY CURRENT VS TIME IN SECOND

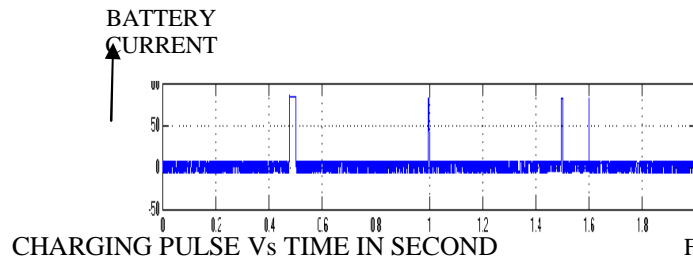
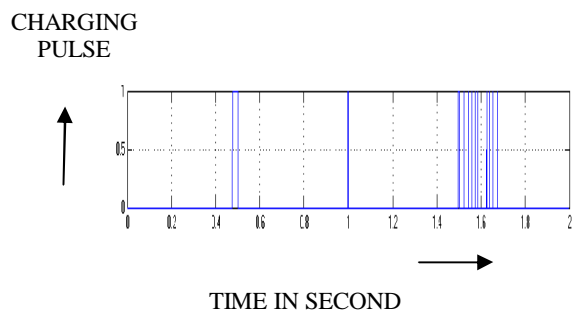
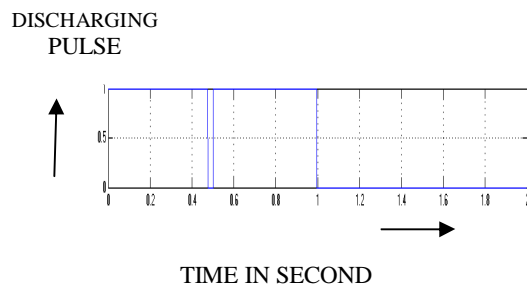


Fig.-8 Circuit Diagram for Proposed System



DISCHARGING PULSE Vs TIME IN SECOND



VIII. HARDWARE IMPLEMENTATION

CIRCUIT DIAGRAM FOR PROPOSED SYSTEM:

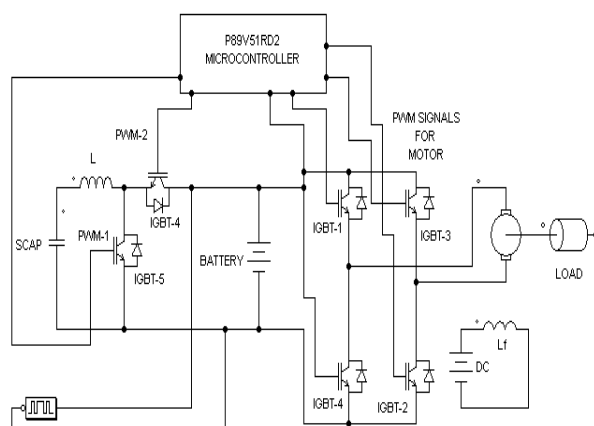
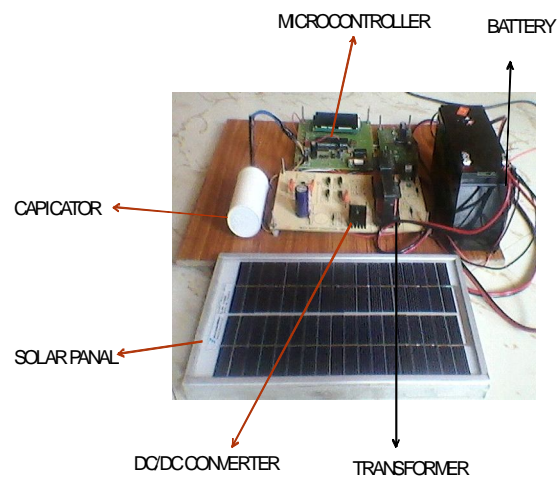


PHOTO IMAGE OF HARDWARE KIT



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